AL.2.1986-1624

REPORT 1979/1

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Erosion Control at Stream/Road Crossings, Hinton/Edson, Alberta 1974-75

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Final Report

Erosion Control At Road-Stream Crossings
Hinton-Edson Alberta, 1974-1975

by
Richard L. Rothwell

Submitted to

Alberta Environmental Research Secretariat
Edmonton, Alberta
1979

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EROSION CONTROL AT ROAD-STREAM CROSSINGS
HINTON-EDSON ALBERTA, 1974-1975

INTRODUCTION

The largest sources of erosion, sediment and water quality deterioration in forested areas are caused by logging and road construction. Erosion occurs when mineral soils are disturbed and exposed, by excavation or log skidding to the erosive forces of raindrop impact and flowing water. Water quality problems are caused by inorganic sediment a product of erosion. Sediments are transported and deposited in stream channels by overland flow. Sediments can be major pollutants and have deleterious effects on the survival, reproduction and growth of aquatic fauna (eg. fish). Increased sediment loads can also be considered a pollutant by increasing the cost of municipal water supplies, reducing the effectiveness of irrigation water by clogging soil pores and silting canals and by reducing the recreational and aesthetic values of water.

Roads and road construction are a greater threat to water quality than logging. In timber harvesting as much as 90 per cent (Anderson, et al., 1976) of the erosion and sediment produced comes from roads. Most of the damage to water values originates from roads with steep gradients, deep cut and fill sections, poor drainage, erodible soils or road-stream crossings.

Road-stream crossings or contacts are the most frequent sources of erosion and sediment causing water quality deterioration. Steep slopes at stream crossings favor the collection of water on road surfaces and in roadside ditches, and its direct discharge with sediment into stream channels. Maximum erosion and sediment usually occur during snowmelt or intense, long duration rainstorms; and increase with the extent of soil disturbance and increasing road gradient.

The volume of erosion and sediment at road-stream crossings can be large. During non-storm periods sediment production at 40 stream-crossings in the Hinton area averaged 29 kg/day (Rothwell, 1974). Sediment production from the same crossings during a storm of 6.25 cm rainfall averaged 370 kg/day, with maximum values as high as 14500 kg/day. Sediment levels as high as these can be harmful to aquatic fauna and aquatic habitats.

Many different methods and materials are available for the control of erosion and sedimentation in streams. Revegetation of disturbed sites is the most common and direct method for erosion and sediment control. Revegetation often consists of direct seeding of grass in a water-seed-fertilizer mixture (ie. hydro-seeding) to bare soils along roadsides. In most situations hydro-seeding results in satisfactory revegetation and erosion control of disturbed areas. However at road-stream crossings characterized by steep slopes and deep excavation revegetation is often unsuccessful. Seedbed conditions along roads are usually poor because of infertile, erodible soils exposed by excavation. More important however is the interaction of steep slopes and overland flow, which can wash seed away before it can become established and provide protection against erosion and sediment.

Intensive cultural practices such as mulching are not commonly used on forest roads. Major objections to such practices are that materials and machinery are too expensive. An alternative to expensive materials is to use logging debris from road right-of-way clearings or cut blocks as a mulch. This technique, commonly called a "brush mulch" or "brush mat", has often been suggested as an effective method for erosion and sediment control (Dumanski et al., 1972). The idea is not new to Alberta, it was studied and used for erosion control in oil and gas fields in the Swan Hills (Wyldman, 1971). A brush mulch consists of logs, tree tops and branches unformly distributed over the ground.

Wyldman (1971), in a comparative study of different mulching methods, rated the brush mulch most advantageous because of its effectiveness in controlling erosion and because the material was readily available and could be easily and economically applied with construction machinery. Packer (1967) also found logging debris to be effective for erosion control. Minimum sediment movement from roads occured when surface obstructions on lower slopes were one of the following: large talus rocks, logs, or large size logging debris.

OBJECTIVES

The main objective of this study was to determine the value of brush mulching for erosion control on forest roads. To achieve this a cooperative study including the following agencies was established: Alberta Environment Research Secretariat, North Western Pulp and Power Ltd., Alberta Forest Service, Alberta Fish and Wildlife Division, and Canadian Forestry Service. In more precise terms the objective of the study was to evaluate how effective a brush mulch is in controlling erosion and sediment movement into streams at road crossings.

STUDY AREA

The study was conducted on the forest management area of North Western Pulp and Power Ltd. The area is located 272 km west of Edmonton and surrounds the towns of Hinton and Edson (Figure 1). The area is 7770 km^2 in size and is characterized by a series of relatively high, flat plateaus and benchlands, separated by wide valleys and lowlands. The entire area is forested, except for a small area around Edson. Major tree species are: Lodgepole pine (*Pinus contorta* var. latifolia), white spruce (*Picea glauca* (Moench)(Voss)), black spruce (*Picea mariana* (Mill)(BSP)), and trembling aspen (*Populus tremuloides*

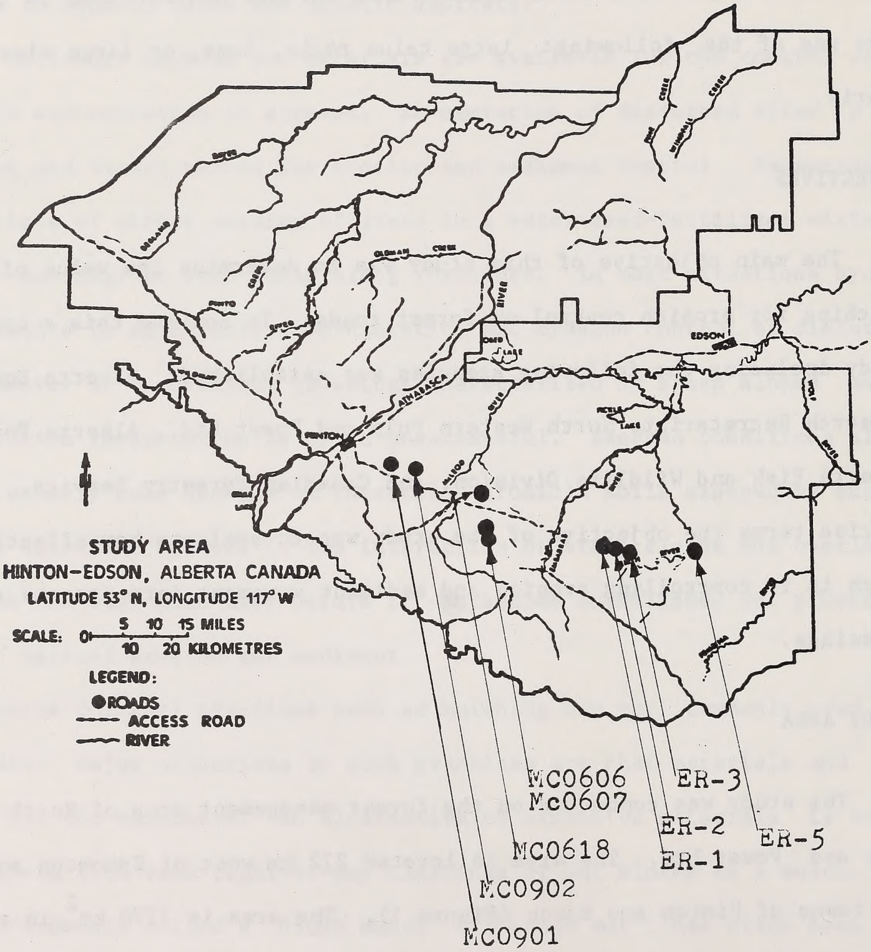

STUDY AREA
HINTON-EDSON, ALBERTA CANADA
LATITUDE 53° N, LONGITUDE 117° W
SCALE: 0 5 10 15 MILES
10 20 KILOMETRES
LEGEND:
● ROADS
ACCESS ROAD
RIVER
HINTON
EDSON
ATHABASCA
RIVER
OLDMAN CREEK
PINTO
CREEK
OBED
LAKE
PICKLE
LAKE
CREEK
MC0606
Mc0607
MC0618
MC0902
MC0901
ER-3
ER-2
ER-1
ER-5

FIGURE 1

Michx).

Dumanski et al. (1972) have identified the major soil profile types in the area as Orthic Gray Luvisol, Bisequa Gray Luvisol, and Eutric Brunisol; their distribution is related to landform, soil reaction and lithology. The soils are medium to coarse in texture (0.25 - 1.00 mm diameter of primary particles) with carbonate contents ranging from low to high (1 - 25% $CaCO_3$ equiv.) and vary from silt loams to loams. Infiltration rates for the various soil associations on lodgepole pine forests were 14.2 cm/hr compared to 2.1 cm/hr for spruce-fir sites (Singh, 1976, unpubl. data). The soils vary in erodibility from low to high. The most erodible soils are those derived from lacustrine and alluvial deposits.

The climate is continential with long, cold winters and short cool summers. Annual precipitation averages between 508 - 533 mm, with 304 - 330 mm occuring as rain between May and September (Alberta Environment, 1972). Mean annual and mean summer temperatures are $1^{o}C$ and $12 - 13^{o}C$ respectively.

The forest management area is divided into several working circles, each with extensive road networks for transport of logs to the pulp mill at Hinton. Main haul roads or first class roads, are built and designed to high standards for continual use throughout the 160 year rotation. Second class roads are for transport and access between cutting compartments within each working circle and are designed for a life expectancy of 20 years. Third and fourth class roads are for transport and access within compartments and between cut blocks, and are designed for a life expectancy of 2 - 10 years. New roads are continually being constructed 1 - 2 years in advance of logging as harvesting moves to new areas. Accordingly, each working circle has a mixed group of old unused roads, currently used roads and newly constructed roads in it. (See Appendix I for summary of NWPP road standards).

Erosion on North Western's main haul roads occurs frequently, with an average distance of 13 km between problems (Schultz, 1973). Approximately 25 per cent of these problems were rated as major erosion, with the remainder rated as a minor erosion (Schultz, 1973).[1] Many of these problem sites occur at road-stream crossings, characterized by extensive soil exposure, deep cut and fill sections, steep slopes, south facing slopes and erodible soils. Erosion and sediment are greatest during and following road construction and usually decrease in 3 - 5 years if revegetation is successful. However, revegetation of these sites is very difficult and often requires repeated operations to control erosion and sediment.

METHODS

The value of brush mulching for erosion control was evaluated by comparing suspended sediment levels at road-stream crossings seeded to grass with and without a brush mulch. Evaluation of the method was based on measurements of: suspended sediment; streamflow; precipitation; the number, volume and composition of aquatic invertebrates; and roadside aesthetics at road-stream crossings.

The study developed in two phases. The first phase was carried out in the summer of 1974. The initial study design compared sediment production at mulched and unmulched crossings by the null hypothesis using Student's t-test (Steel and Torrie, 1956), with six replications for each treatment. The treatments were to be applied to newly constructed road crossings, no more than 1 year old, at perennial streams. However, field reconniassances in 1974 indicated that there were not enough newly constructed crossings in the forest management area to support the proposed level of replications and that it would be difficult to obtain crossings homogenous in slope steepness, soils, stream size and road geometry. Because of these problems, the level of replication was reduced to three per treatment, which required a total of six sites for the study (ie. 2 Trt. x 3 Repl. = 6 sites).

---

[1] Minor erosion: Ditch erosion up to 3 feet deep, sheet erosion.
Major erosion: Washouts at streams, ditch erosion over 3 feet deep.

Unfortunately, only five sites were identified in 1974 as suitable for study and two of them were not used because of poor access or excessive travel distances. The three remaining crossings were treated, two seeded with a mulch and one seeded without a mulch. The treatments were randomly assigned to the crossings. The sites are located approximately 18 km east of the village of Robb, in the Erith River drainage, and are within 1 - 2 km of each other (Figure 1).

The second phase was done in the summer of 1975. The study was modified to overcome the difficulties encountered in 1974. To increase sample size and to reduce heterogeneity in the sample population, study sites were selected from existing road-stream crossings (ie. a greater total population). The sites selected were prepared to resemble newly constructed road crossings, by scarification or removal of all vegetation and organic material from the soil surface. The Canadian Forestry Service, Alberta Forest Service, and Fish and Wildlife Division in joint field reconniassances examined 15 - 20 sites in 1975. Selection criteria used were:

- stream size and flow: streams perennial in flow to ensure habitat for aquatic invertebrates, and continuous measurement of sediment. Mean summer flows should range from 0.05 - 0.50 m^3/sec.

- stream channel bed material: channel bed material should have clean gravel and riffles above and below road crossings to ensure good habitat and sampling for aquatic invertebrates.

- stream crossing approach: alignment of road in crossing stream should be straight and perpendicular to stream. This assures a direct path for overland flow to the stream channel and potential for detection of road effects.

- stream channel alignment: stream channel between upstream and downstream sample points should be relatively straight, with no ponding or backwater to ensure consistent sediment sampling.

- treatment area: total area for treatment should not exceed 3.0 ha. If larger, resources for study would be exceeded.
- access: all weather access to a site is required, so that observations can be made during storm periods.

Six road-stream crossings were selected for treatment and study in 1975. Satisfaction of all selection criteria was very difficult. The selected sites are located south of Hinton, either along the Forestry Trunk Road or the Erith River Road (Figure 1). All crossings occured on either second class or third class roads. Five of the crossings were culverts and one a bridge. Road standards involved were: road right-of-way clearing of 40 m; road bed width of 8.5 m; road gradients on approaches of 5 - 9 per cent; fill depths of 1.5 - 4 m; and very gentle to moderately steep sloping cuts and shoulders (Table 1). In most cases, roads were aligned perpendicular to stream channels, with parallel drainage ditches. On some sites, ditch blocks and off-take ditches had been installed during road construction to either trap sediment or divert runoff onto undisturbed areas. These structures were left intact during site preparation, because they were considered normal construction practices.

The two treatments in the study were designated as (1) mulch - a direct seeding of a grass-fertilizer mixture on soil prepared with a brush mulch; and (2) unmulched - a direct seeding of a grass-fertilizer mixture on bare soil. The method of treatment application was the same in both years, except for site preparation in 1975 to simulate newly constructed road crossings. Site preparation or scarification of each crossing involved in the removal of existing vegetation and organic material on road shoulders, ditches and backslopes, and grading of bare soils to smooth surfaces. Scarification extended upslope from each stream bank to the topographic divide or first major change in slope. A "D7 - D6 Caterpillar" type tractor was used to remove vegetation. This machine was unable to operate near some streambanks and lower slopes, because of wet soils. In particular, small patches of existing vegetation were not removed from crossing

TABLE 1. Road Crossing Descriptions.

Site	TRT.	Area ha	% Road	% Shoulder	% Backslope	Type Crossing	Fill M	Road M	Road Grade	Ditch M	Ditch Grade	Elev. M
ER-1	G+M	0.92	--	--	--	C	--	--	--	--	--	
ER-2	G+M	1.01	--	--	--	C	--	--	--	--	--	
ER-3	G	1.52	--	--	--	C	--	--	--	--	--	
MC0901	G+M	1.161	24	16	43	C	3.4	305	9 3	556	11 4	12.0
MC0902	G	0.44	29	36	35	C	3.6	168	7 1	362	10 7	9.7
MC0607	G	2.16	20	31	49	C	2.4	610	8 3	564	14 7	24
ER-5	G+M	0.75	17	23	50	B	--	396	8 6	899	10 6	17
MC0618	G	0.62	25	23	52	C	2.1	213	5 4	442	4 2	7
MC0606	G+M	0.92	22	30	48	C	1.8	457	7 6	884	7 -	27
Mean	--	1.05	23	27	46	--	2.7	358	7 4	482	9 5	16

TRT = Treatment: G+M = Grass + Mulch; G = Grass Only
Type Crossing: C = Culvert; B = Bridge
Fill = Depth of Fill Section Over Culvert - M
Road = Total Lineal Road Distance in Treatment Area - M
Road Grade = Road Gradient Approaches to Stream - %
Ditch = Total Lineal Ditch Distance in Treatment Area - M
Ditch Grade = Ditch Gradient Approaches to Stream - %
Elev. = Elevation Relief Along Road Centerline in Treatment Area - M

MC0607 and only one-half of crossing MC0606 could be treated because of wet soil conditions. This was not considered a disadvantage, because the untreated part of MC0606 is dominated by grassy muskeg and does not contribute sediment to the stream.

The brush mulch was logging debris obtained from nearby areas, consisting of logs 2 - 15 cm in diameter, tree tops and loose branches. The debris was laid on the ground parallel to the contour or across the expected flow of water (Figure 2). The brush mulch was applied by hand to road shoulders, ditches and backslopes in one to two days. The average size of treated areas was 1 ha. Using Packer's results (1967) as a guide, the debris was spaced 60 - 120 cm apart, with the close spacing used on steep areas, such as backslopes. The debris was "anchored" in place by driving a tractor over it to partially push it into the ground. Seeding and fertilizing followed mulching.

In both treatments the grass seed-fertilizer mixture was applied to road shoulders, ditches and backslopes with a Reinco Hydro-Seeder, model H68A. The grass mixture used was creeping red fescue (30%) (Festuca rubra L.), red clover (30%) (Trifolium hybridum L.), perennial rye (20%)(Lolium sp.), and fall rye (20%) (Lolium sp.) applied at a rate of 9 kg/ha. The fertilizer used was Engro 16-20-0, applied at a rate of 37 kg/ha. Seeding on all crossings was done in late May or early June.

Treatments were compared and evaluated by measurements of suspended sediment production and aquatic fauna above and below road stream crossings and a photographic history of each site. Sediment production[2] from a road crossing was assumed to be the difference between sediment concentrations of samples

---

[2] Sediment Production = (down - up)(streamflow)(constant)
down = downstream sediment concentration mg/l
up = upstream sediment concentration mg/l
streamflow = volume flow water m^3/sec
constant = conversion to express sediment flow in kg/day

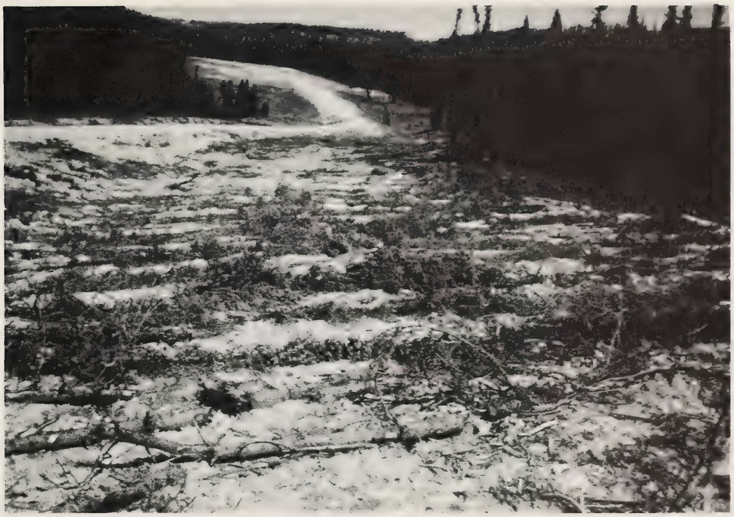


Figure 2. Logging debris laid on the ground parallel to contour to slow water and trap sediment.

obtained above and below a road. It was assumed that downstream sediment concentrations would exceed upstream values because of erosion and sediment from the intervening road. It was also assumed that erosion and sediment would cause a change in the number and/or composition of aquatic organisms downstream from a road.

Measurements of suspended sediment, streamflow, stage, and precipitation at each crossing were started following treatment application. Measurements were taken 2 - 3 times weekly during non-storm periods. Measurements during storm periods were taken every 4 hours daily from 0600-2200 hours, for a 72 - 96 hour period to obtain a record of storm-sediment hydrographs. This was essential, because 90 percent of annual or seasonal erosion and sediment can be generated by a single storm.

Sediment samples were collected with a U.S. Geological Survey DH48A depth integrating, hand sediment sampler. Sampling stations, upstream and downstream, coincided with road right-away boundaries or the upper and lower limits of soil disturbance. Sediment samples were transported to Edmonton for analysis. Sediment was separated by filtration using glass fiber filter paper and expressed in units of milligrams per liter (American Public Health Association, 1965). Minimum size particles retained in filtration were between 0.0008 - 0.0013 mm (ie. 0.75 - 1.25 microns, or clay-silt size fraction).

Streamflow and stage at each crossing were measured at the downstream sediment sampling station in natural channel sections with a Price type current meter and standard staff gauge. Measurements were obtained in English units and later converted to metric equivalents. Stage and flow measurements were used to develop separate rating curves for each stream crossing.

Precipitation at each crossing was measured in a standard m.s.c. raingauge (Bruce and Clark, 1967), which is 4.33 cm in height with an orifice diameter of 1.40 cm. In addition, a continuous record of precipitation and rainfall intensity was obtained from two Universal precipitation gauges (U.S.D.A. 1962) installed in the study area.

To determine the size of treated areas and to obtain a detailed description of ground surface conditions, a level survey was done at each crossing. The elevations of the road centerline, shoulders, ditch grades, and backslopes were determined on road cross-sections at intervals of 15 - 30 m for the length of each treated area (Appendix III). These data were used to construct a plane view map of each crossing and to identify and to map sources of erosion. To illustrate differences and similarities between crossings, exaggerated 3-dimensional sketches were produced by orthographic projection (Appendix III). Besides the level surveys, 2 permanent photo-plots per road quadrant were established at each crossing.

Measurement and study of aquatic invertebrates were done in 1974 and 1975. Invertebrate sampling in 1974 was done once at each crossing, measuring the number and volume of organisms and sorting them by order only. Samples were taken from the first 2 - 3 riffles immediately above and below roads. In 1975, sampling was intensified with observations every 4 - 6 weeks through spring and summer. Samples sites extended 100 - 200 m above and below roads and were in as similar riffles as possible. Invertebrates in each sample were identified by genus, counted, and measured for volume.

Samples were taken with both dip nets (mesh size 1 mm) and the one foot square (0.09 m^2) Surber sampler (mesh size 420 microns or 0.42 mm). The number of Surber samples per site varied from five in Hanlan Creek (ER-5), which is 7 - 10 m wide, to two samples in Felton Creek (MC0607) and McPherson Creek (MC0902) which are 0.5 - 1.0 m wide.

The impact of roads on aquatic invertebrates were determined by calculation and comparison of species diversity indexes (Warren, 1971) for stream sections above and below roads. A diversity index is simple to use and considers the "richness" of species, and the distribution or numbers of species within a community. The index is determined by calculating an expected value ($\bar{H}$) based on the number of organisms (N) in all species, and the number of organisms in the i'th species (N_i). Expressed in formula:

$$\bar{H} = -\Sigma(N_i/N) \log_2 (N_i/N).$$

To test for significance between the above and below sites a modified t-test was employed (Poole, 1974).[3]

Resident fish populations were studied in 1974 to confirm the existence and composition of fish in small streams. Sampling was done by electrofishing techniques, with surveys made on 1000 m sections above and below road crossings, starting at culvert outlets and inlets. Two surveys were made on each stream, an initial survey followed by a "recapture" survey, 2 - 3 days later. All fish caught were identified by species, measured for length, marked by clipping a rear ventral fin and released.

RESULTS

Sediment data for 1974 and 1975 showed similar results, however analyses and tests of significance are limited to the 1975 observations. The 1975 data are considered more reliable because of greater sample population and sample size.

Sediment production from unmulched crossings in 1975 averaged 4 - 5 times more than that from the mulched crossings. Mean suspended sediment concentrations at upstream and downstream sites for unmulched crossings averaged 11 and 33 mg/1 respectively, while those for mulched sites averaged 11 and 20 mg/1 (Table 2).

---

[3] Collection and analysis of aquatic invertebrate data was done by Mr. G. Bergstrom, Land Use Branch, Alberta Forest Service, Department Energy and Renewable Resources, Edmonton, Alberta.

Mean seasonal sediment production (May-August) in kg/ha/day for mulched and unmulched crossings are 26 and 105 respectively. Student's t-test shows significant differences between the treatment means at the 70 per cent probability level (ie. 4 out of 5 times such differences are caused by something other than random chance - Table 3). Mean values for individual mulched and unmulched crossings varied from 24-208 and 20-933 kg/ha/day respectively.

Storm sediment data were also analyzed. Sediment concentrations during storm periods at all road-stream crossings increased by 150 - 340 percent. Differences between treatments were similar to the seasonal values, only being greater in magnitude and variability. Mean storm sediment production for mulched and unmulched crossings were 161 and 400 kg/ha/day respectively. Student's t-test of the treatment means shows significant differences to exist at the 70 percent probability level (Table 3).

On the bases of the statistical tests alone, it is difficult to say the brush mulch is a more effective treatment, because of the low levels of significance and the high variation in the data. Part of the observed treatment differences result from inherent differences between the crossings in topography and road geometry. Frequent on-site road inspections during and after rainstorms identified some of these differences, and also showed that brush mulching was effective for erosion and sediment control.

Road inspections from 1974 - 1976 showed erosion and sediment at mulched crossings to be less frequent and less severe than at unmulched crossings. On mulched sites erosion was less because the velocity of overland flow was reduced and sediment was trapped on the uphill sides of logging debris (Figure 3). In many instances, the capacity of small debris, 25 - 50 mm in diameter, was exceeded in 1 - 2 rainstorms. Erosion on mulched crossings occured most often in roadsides ditches, on fill slopes and upper backslopes where vegetation was sparse, or where logging debris was undercut or washed away by overland flow.

TABLE 2. Mean Suspended Sediment Concentrations, Sediment Production and Streamflow on Seasonal and Storm Bases for 1974, 1975.

Site	Date	Treatments						
		Grass and Mulch			Grass			Mean Streamflow
		Sediment mg/1 Up	Sediment mg/1 Down	kg/d/ha	Sediment mg/1 Up	Sediment mg/1 Down	kg/d/ha	m^3/sec
	SEASONAL							
ER1	1974	10	66	494				0.049
ER2	1974	30	156	1069				0.074
ER3	1974				24	309	756	0.015
ER1	1975	30	42	122				0.039
ER2	1975	45	59	112				0.078
ER3	1975				55	516	1307	0.034
MC0901	1975	13	37	268				0.044
MC0606	1975	12	9	15				0.083
ER5	1975	12	13	100				0.905
MC0902	1975				7	35	1549	0.044
MC0607	1975				20	59	183	0.041
MC0618	1975				6	6	27	0.047
	STORMS							
ER1	June 21-28, 1974	12	57	304				0.055
ER2		29	285	2012				0.080
ER3					42	640	1474	0.038
ER1	July 9 - 13, 1974	17	61	496				0.094
ER2		145	551	3391				0.259
ER3					91	1084	2489	0.099
ER1	June 28-30, 1975	84	121	232				0.055
ER2		119	140	2939				0.128
ER3					89	1539	2739	0.041
MC0901	June 28-30, 1975	18	110	999				0.132
MC0606		10	18	112				0.077
ER5		35	40	838				1.698
MC0902					9	117	5793	0.140
MC0607					63	201	721	0.133
MC0618					4	9	108	0.117

TABLE 2 - continued

		Overall Means - All Sites Pooled	
		Grass + Mulch kg/d/ha	Grass kg/d/ha
SEASONAL			
	ER1, ER2, ER3		
	1974	781	756
	1975	117	1307
	MC0901, MC0606, ER5 MC0902, MC0607, MC0618		
	1975	128	586
STORM			
	ER1, ER2, ER3		
	1974	1550	1981
	1975	1585	2739
	MC0901, MC0606, ER5 MC0902, MC0607, MC0618		
	1975	650	2207

TABLE 3. Results of Student's t-test between Mulched and Unmulched Treatments, 1975.

Sediment Production -- lbs/day/acre

Seasonal Sediment Production for May-August 1975 = Summation of daily sediment production.

Treatments	Mulch		Unmulched
MC0901	4766(2166 kg)	MC0902	56889(25858 kg)
MC0606	1100(500)	MC0607	7369(3349)
ER 5	10491(4768)	MC0618	1173(53)
Mean	5455(2479)		21802(9910)

Pooled standard deviation = 21853 = S

$$t = \frac{\bar{X}\text{mulch} + \bar{X}\text{unmulched}}{S}\sqrt{\frac{n}{2}} = \frac{5455 + 21802}{21853}\sqrt{\frac{3}{2}} = 1.2247$$

Tabulated t values 95% 2.78
80% 1.50 vs. 1.23
70% 1.19

Storm Sediment Production = Summation of storm sediment production.

Treatments	Mulch		Unmulched
MC0901	3692 (1678 kg)	MC0902	57081(25954 kg)
MC0606	1322(601)	MC0607	7149(3249)
ER 5	9096(4134)	MC0618	1072(487)
Mean	4306(1957)		21767(9894)

Pooled standard deviation = 21913 = S

$$t = \frac{\bar{X}\text{mulch} + \bar{X}\text{unmulched}}{S}\sqrt{\frac{n}{2}} = \frac{4306 + 21767}{21913}\sqrt{\frac{3}{2}} = 1.4572$$

Tabulated t values 95% 2.78
80% 1.50 vs. 1.46
70% 1.19

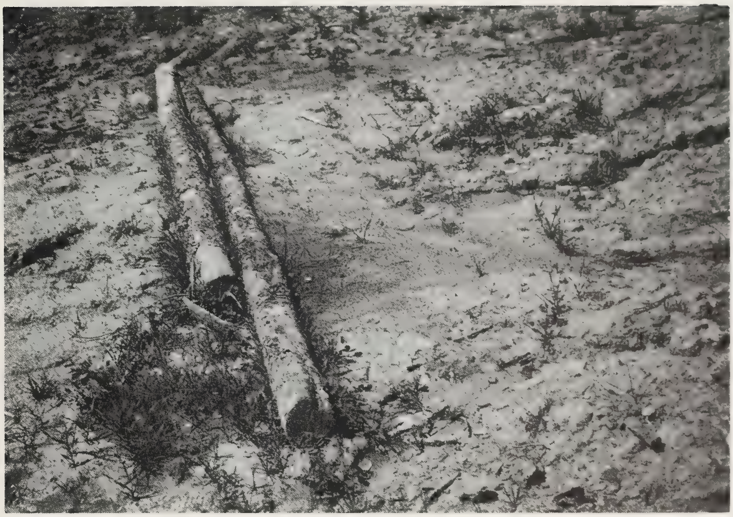


Figure 3. Sediment trapped on the uphill sides of logging debris.

Erosion was most severe in roadside ditches and on culvert fill sections.

Erosion at unmulched sites was very obvious. Immediately after treatment and the first rainstorm, the treatment areas were covered with extensive systems of rills and gullies. The rills were 25 - 50 mm deep and the gullies were 0.5 - 1.0 m deep. Gully erosion usually occured in association with roadside ditches. Maximum erosion and sediment transport into stream channels were again from roadside ditches and culvert fill sections.

Sediment deposits in stream channels occured as deltas immediately above and below road crossings where ditches or gullies intersected stream channels. Such deposits are common at crossings during storms and usually are small and quickly washed away by stream flow. At the unmulched crossings in this study the deposits were larger in size than those observed at mulched crossings, occured more frequently and increased in size with each storm instead of being washed away. At one crossing (MC0607) deposition was so great that streamflow was diverted away from the culvert inlet and the channel downstream from the road was covered with sediments 30 cm deep for a distance of 1000 m.

Causes for high variability in sediment production and deposition between crossings and within treatments became apparent during road inspections. The high variability in the data were caused by differences in topography and road geometry between crossings. Differences in soil erodibility were not considered important, because of the similarity of soils and parent materials at all crossings. The biggest differences between crossings were in slope steepness, slope length, road alignment, and depth of cut and fill sections. For example, high sediment loads at two of the 1974 sites (ER-1, ER-3) resulted from erosion and slumping of fill sections, which completely buried culvert inlets and outlets (Figure 4). Another cause of heavy sediment loads was the use of off-take ditches at crossings with short, steep slopes. In such situations there was not

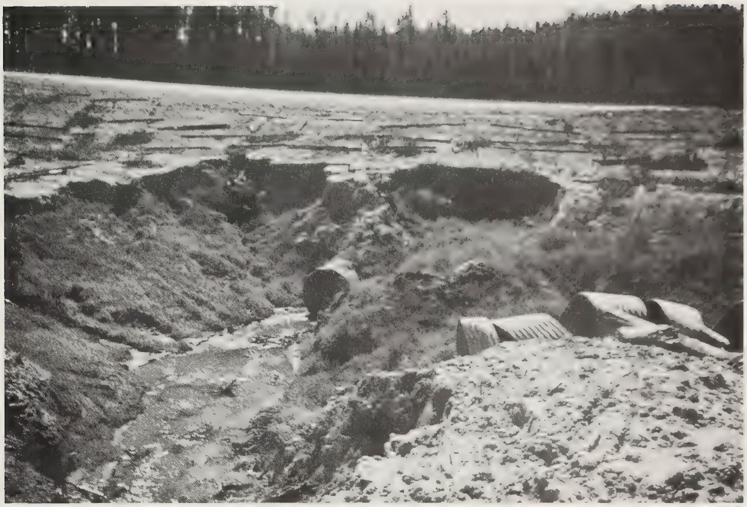


Figure 4. Excessive erosion and slumping of road fill section.

enough slope distance for ditches to be turned away from stream channels (ie. too small a turning radius) which results in direct sediment discharge into streams. Low sediment at another site (MC0618) resulted from a low road gradient approach to the stream and road alignment that diverted most sediment away from the stream.

Revegetation of both mulched and unmulched stream crossings was good. All sites were seeded with the same species in late May or early June. Sowings in 1974 and 1975 were followed by gentle rainfall and cool weather that resulted in good germination. Grass on the mulched crossings however appeared 1 - 2 weeks earlier than on unmulched crossings, and was more widespread, dense and uniform in distribution. The initial appearance of grass coincided with the brush mulch. Grass occured first in and around the edges of logging debris (Figure 5), with intervening areas later occupied by subsequent growth in the following year. The general distribution and earlier germination of grass on the mulched sites is assumed to result from the logging debris preventing grass seed from being washed away, and the occurence of extra shade and soil moisture around the edges of logging debris.

Initial revegetation on mulched crossings was good, but more sparse and irregular in distribution than on mulched crossings. Grass germination and growth were greatest in small ground surface depressions such as rills and tractor tracks, and at the bottom of slopes. This distribution is assumed to result from overland flow washing and redistributing grass seed. The depressions also provided some extra shade and soil moisture favorable to grass establishment. Grass cover on the unmulched sites at the end of the first summer was still visibly less than that on the end of the first.

Observations of revegetation at crossings 2 - 3 years after sowing (1976, 1977) showed grass cover at mulched and unmulched crossings to be roughly equivalent. A comparison of biomass at a mulched and unmulched crossings (MC090]), (MC0902) by randomly located clipping plots, 1 m^2 in size, showed no significant differences. All crossings were satisfactorily revegetated except for infrequent bare, eroding soil areas. These areas varied in size from small to moderate and were localized to roadside ditches, fill sections and steep backslopes. Their existence is considered the result of harsh site conditions, which would have occurred to some degree regardless of treatment.

A final observation on revegetation is that grass germination and growth were very successful in depressions made by tractor tracks (Figure 6). On most sites the soils were moderately textured tills, such that the tracks were well defined, 2 - 5 cm deep, and relatively resistent to erosion. The long axes of the depressions were often parallel to contours, which resulted in the collection of overland flow, sediments, and grass seed and the provision of shade and moisture favorable to germination (Figure 6). The effects of the depressions are similar to contour ploughing which suggests surface cultivation, instead of grooming roadside areas smooth, could be an effective technique for revegetation.

The results for the surveys of fish and aquatic invertebrates are shown in Tables 4 and 5. Electrofishing above and below stream crossings treated in 1974 and visual observations of the 1975 crossings showed that all streams had resident fish populations. Species encountered were: dolly varden trout (_Salvelinus malma_ (Wabaum)); rainbow trout (_Salmo gairdneri_ Richardson); mountain whitefish (_Prosopium williamsoni_ (Girard)); and dace (_Chrosomus spp._). The fish were small averaging 5 - 6 cm in length with occasional large dolly varden ranging up to a maximum of 60 cm in length. The mountain whitefish appeared to be transients, moving back and forth between larger streams and rivers, and the study streams. The study streams are not important for sport fishing, but may be significant for

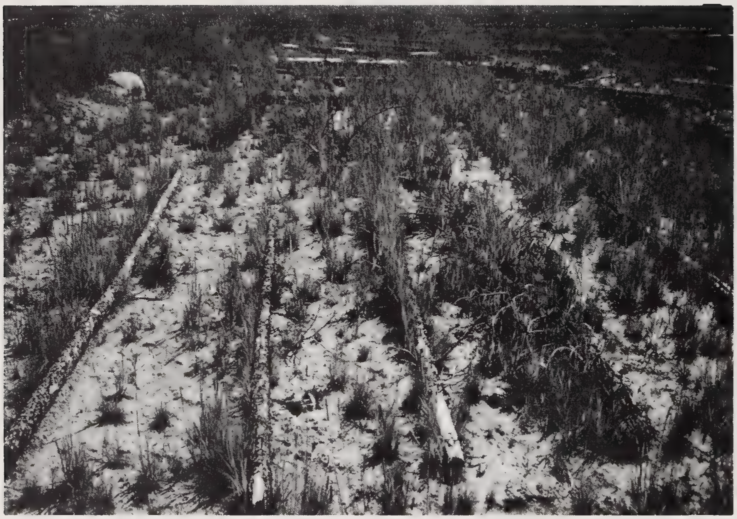


Figure 5. Initial grass germination on mulched sites occured around the edges of logging debris.

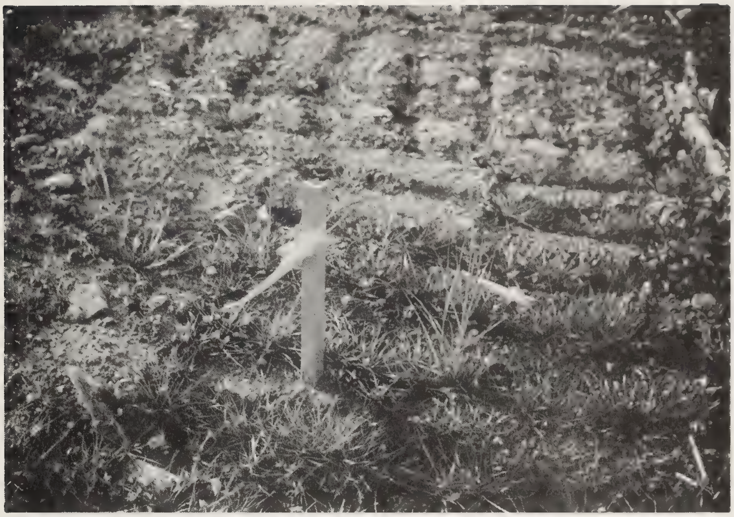


Figure 6 Grass germination and growth were very successful in depressions left by tractors tracks. Small depressions oriented parallel to the contour are similar to contour ploughing.

TABEL 4. Electrofishing Surveys of Roadstream Crossing ER1, 1975, 500 m Section Downstream of Road Crossing.

Date	Dolly Varden Trout	Rainbow Trout	Mountain Whitefish	Others
July 7				
numbers	4.0	8	3	--
mean length - cm	18.0	12.75	17.3	--
standard deviation	20.0	2.70	2.0	--
maximum length - cm	48.5	17.0	19	--
minimum length - cm	8.0	10.0	25	--
July 23				
numbers	12	28	3	2 (sculpins)
mean length - cm	13.3	14.7	24.7	10.9
standard deviation	11.5	6.18	3.20	--
maximum length - cm	48.5	44.0	28.0	12.6
minimum length - cm	6.5	10.0	21.5	9.3
August 8				
numbers	14	17	10	--
mean length - cm	23.3	14.3	26.0	--
standard deviation	17.0	3.09	23.0	--
maximum length - cm	56.0	19.0	30.0	--
minimum length - cm	9.5	6.5	23.0	--

spawning and/or rearing of fish for larger downstream waters.

Aquatic invertebrate sampling in 1975 was restricted to crossings ER-5 MC0902 and MC0607, because they were most suitable for study in terms of habitat and fauna. The other streams were unsuitable because of either low invertebrate numbers or stream channel conditions what made sampling difficult.

The results of the Surber samples are shown in Table 6. The data for ER-5 shows the downstream sampling station had higher numbers of organisms and significantly higher diversity indexes than the upstream station. An inspection of the stations showed the downstream area was mainly composed of gravel (0.2 - 6.4 cm diameter) with little sand or silt, while the upstream station contained sand. These conditions, plus the composition of clean water organisms present suggest that the downstream site is more productive and that little if any damage from the road could be detected during the summer sampling period. It should also be noted that Hanlan Creek (ER-5) flows are large relative to the other study streams, which indicates a higher potential for cleaning or flushing of fines from substrate.

The data for MC0607 is quite different, with all of the upstream samples showing high numbers of organisms and greater diversity indexes. The substrate material of the upstream station was composed mainly of rubble (6.6 - 25.4 cm in diameter) with some boulders (125.4 cm in diameter), while the downstream area was composed of mainly sand with very little gravel. The abrupt change in streambed material is attributed to inputs of sediments from the road. Examination of the road-stream crossing shows that severe erosion of the southwest roadside ditch resulted in high deposition of sand, gravel and rock in the downstream section of the stream channel (Figure 4, Appendix III). These conditions and the differences in numbers and diversity indexes indicate that the downstream is non-productive in aquatic invertebrates.

The data for MC0902 indicate that the upstream sampling station had higher

TABLE 5. Aquatic Invertebrate Surber Samples Obtained Above and Below Road Stream Crossings - 1975.

				GENSUS						
	ABOVE					BELOW				
Road Crossing	Ephemeroptera	Plecoptera	Tricoptera	Diptera	Total	Ephemeroptera	Plecoptera	Tricoptera	Diptera	Total
ER5										
May 27	36	36	0	17	89	104	214	2	45	365
July 2	111	41	6	19	77	28	33	0	3	64
July 24	90	45	1	26	162	298	96	3	49	446
August 20	72	32	0	49	153	131	135	23	79	368
MC0607										
July 8	80	44	18	183	325	43	7	46	33	129
July 30	37	26	15	109	187	11	4	0	13	28
August 20	15	27	11	156	209	84	65	2	283	434
MC0902										
July 8	16	16	1	32	65	5	11	3	130	149
July 29	1	23	11	25	60	77	27	1	101	106

TABLE 6. Results of modified t-test, total number of organisms, and diversity indexes for aquatic invertebrates samples obtained from Suber samples, 1975.

Site	Sampling Dates							
	5/27/75		7/2/75		7/24/75		8/20/75	
ER 5	up	down	up	down	up	down	up	down
TOTAL No.	45	139	177	64	162	446	168	368
Diversity Index	1.79	1.44	1.90	1.34	1.61	1.75	1.90	2.36
t-value	2.818*		4.292**		1.92 NS		6.25**	
MC0607			7/8/75		7/3/75		8/20/75	
Total No.			325	129	187	38	209	434
Diversity Index			1.59	1.47	1.88	1.45	1.45	1.12
t-value			1.26 NS		3.92**		3.69**	
MC0902			7/8/75		7/29/75			
Total No.			45	149	60	206		
Diversity Index			1.66	1.33	1.37	1.38		
t-value			2.26*		0.058 NS			

diversity indexes, even though the total number of organisms were less than those in downstream samples. An examination of the area showed that some damage was done to the upstream areas from past logging operations. Because of this and the small number of samples taken the results from this crossing must be viewed with caution. Furthermore, the composition of organisms present are primarily clean water invertebrates, suggesting that the stream was not greatly affected by the road or logging.

CONCLUSIONS

A brush mulch treatment applied at road-stream crossings was more effective in controlling erosion and sediment than a treatment of direct seeding of a grass-fertilizer mixture to bare soil. Storm and seasonal sediment production were respectively 1.5 and 5 times less than sediment production from unmulched crossings. These differences were statistically significant, however the low levels of significance and high variability of data make if difficult to say that the mulch was a more effective treatment. The variability in all cases was identified with differences in topography or road geometry between crossings.

Frequent on-site inspections of road stream crossings during and after rainstorms however, support the conclusion that the brush mulch was more effective in controlling erosion and sediment. Erosion at mulched sites was less frequent and less severe, because overland flow was slowed by logging debris, and sediment was trapped on the upslope sides of logging debris. This contributed to less stream channel sediment deposition at mulched crossings. Sediment deposits at unmulched sites were larger than those at mulched crossings, occured more frequently and often increased in size with each rainstorm.

Maximum benefits of a brush mulch occured immediately after application when soils were bare and unprotectected from the erosive forces of raindrop splash and flowing water. The benefits of the mulch decreased when the sediment trapping capacity of small debris was exceeded in 1 - 2 rainstorms. A brush mulch therefore is a temporary measure providing short-term protection against erosion and sediment until a good vegetative cover is established.

A brush mulch is also advantageous to revegetation of gentle to steep sloping areas. Besides slowing and trapping sediment, a brush mulch can prevent seed from being washed away or buried. This was evident on mulched sites where initial grass germination and growth occured predominantly in or around the edges of logging debris. Furthermore such locations probably enhance germination by providing micro-sites with shade and extra soil moisture.

Vegetation at all crossings 2 - 3 years after sowing showed grass cover at mulched and unmulched sites to be roughly equivalent. All sites were adequately revegetated, except for occassional ditches. These bare soil areas were considered to be the result of poor growing conditions on a harsh site, and would have occured to some degree regardless of treatment. No general deterioration of the agronomic grass species, from a lack of nutrients (ie. repeated fertilizer applications) was evident on any of the crossings.

No definite changes or differences in aquatic invertebrates above and below the road crossings could be directly related to the applied treatments. Analyses of the data for three streams gave variable results. Sampling on two of the streams showed greater diversity indexes for the upstream areas, but a higher number of organisms in the downstream sections. It was concluded that neither of these streams were greatly affected by logging or the road crossings. Observations at the other creek however did show damage from sediment deposition. Both the total number or organisms and diversity indexes were greater for the upstream section. A good amount of this damage occured prior to the spring treatment application of 1975.

In conclusion a brush mulch can be very effective in controlling erosion and reducing sediment movement from roads into streams. However, it is a temporary measure providing protection for 1 - 2 years, until a good vegetation cover is established. Further advantages of a brush mulch are that the material is readily available, can be applied easily and economically with machinery and can be incorporated into normal road building practices.

ACKNOWLEDGEMENTS

Financial assistance for this study was provided by the Research Secretariat of Alberta Environment and is gratefully acknowledged. Special thanks are also due to North Western Pulp and Power Limited and to the Alberta Forest Service and Alberta Fish and Wildlife Divisions of Energy and Natural Resources for their cooperation and contributions of manpower and equipment.

The author is grateful to North Western Pulp and Power Limited for providing and protecting experimental areas for this study.

Literature Cited

Alberta Environment. 1972. Climate of Alberta with data for Yukon and Northwest Territories. Report For. 1972. Queens Printer, Edmonton. 60 pp.

American Public Health Association. 1965. Standard Methods For Examination of Water and Wastewater. (12th ed.) New York. 769 pp.

Anderson, H.W., M.D. Hoover and K.G. Reinhart. 1976. Forests and Water: effects of forest management on floods, sedimentation and water supply. Forest Service, U.S. Department Agriculture, General Technical Report PSW-18/1976, 115 pp.

Bruce, J.P. and R.H. Clark. 1966. Introduction to Hydrometeorology. Pergamon Press. Toronto, 319 pp.

Dumanski, J., T.M. Macyk, C.F. Veauvy and J.D. Lindsay. 1972. Soil Survey and Land Evaluation of the Hinton-Edson Area, Alberta. Alberta Institute of Pedology, Report No. S-72-31. 119 pp. and maps.

Moss, E.H. 1959. The Flora of Alberta. University of Toronto Press. 546 pp.

Packer, P.E. 1967. Criteria For Designing and Locating Roads To Control Sediment. Forest Science, 13:2 - 18.

Paetz, M.J. and J.S. Nelson, 1970. The Fishes of Alberta. Queens Printer, Edmonton. 282 p.

Poole, R.W. 1974. An Introduction to Quatitative Ecology. McGraw-Hill. Toronto. 532 pp.

Rothwell, R.L. 1974. Roads: Major Sediment Source. IN: Forestry Report. Canadian Forestry Service. Northern Forest Research Centre 3(4).

Singh, T. 1975. Unpublished data. Canadian Forestry Service. Northern Forest Research Centre, Edmonton, Alberta.

Schultz, C.D. 1973. The Environmental Effects of Timber Harvesting Operations In the Edson and Grande Prairie Forests of Alberta. Volume I, A report submitted to the Minister of Lands and Forest, Government of Alberta. 291 pp.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill. Toronto. 481 pp.

U.S. Department Agriculture. 1962. Field Manual For Research In Agriculture Hydrology. Agricultural Research Service. U.S. Department Agriculture, Agriculture Handbook No. 224. 215 pp.

Warren, C.E. 1971. Biology and Water Pollution Control. W.B. Saunders Co., Toronto, 434 pp.

Wyldman, E.C. 1974. Oil In Swan Hills. IN: Forestry Report, Canadian Forestry Service Northern Forest Research Centre, Edmonton, 3(4).

APPENDIX I: North Western Pulp and Power LTD.
Road Standards

Source: Schultz. C.D. 1973 The Environmental Effects of Timber Harvesting In Alberta. Report submitted to the Minister of Lands and Forests, Government of Alberta. Volume 2

NORTH WESTERN PULP AND POWER ROAD STANDARDS

Design Standards

Purpose

Class "A" - permanent, all weather
Class "B" - semi-permanent (20 years) all weather
Class "C" - camp access (5 years) all weather
Class "D" - winter haul roads
Class "E" - compartment extraction roads

Geometric Design Standards

Design Element			Road Class				
			I A	II B	* C	III D	V E
Speed			40	30	20	30	30
Alignment Min. Rad. (ft)			573	383	250	383	383
Maximum Gradient Percent	Favorable	Sustained	6	7	7	6	7
		Pitch	8	8	10	8	8
	Adverse	Sustained	3	3	3	3	3
		Pitch	5	5	5	5	5
Minimum sight distance			620'	420'	250'	420'	420'
Maximum right of way (ft)			132'	132'	132'	132'	132'
Width (ft)	Roadbed		28'	28'	24'	28'	28'
	Ditch to Ditch		52'	48'	44'	-	48'
	Surfacing		28'	28'	24'	nil	28'

Fills	under 5 ft.	3:1 slope
	over 5 ft.	1-1/2:1 slope
Cuts	under 5 ft.	2:1 slope
	over 5 ft.	1:1 slope

Superelevation

Radius	Superelevation	Transition Dist.
250-700	.02 feet per foot	75 feet

*No longer used.

NORTH WESTERN PULP & POWER ROAD STANDARD GUIDELINES
SPECIFICATIONS APPLY ON LEVEL GROUND

	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V
Description of Road	Inter-working Circle and Inter Compartment Main Haul Road	Inter-Compartment within a working Circle Secondary Haul	Internal Compartment Lateral Access through Cut Blocks Secondary Haul	Within or between Cut Blocks Strip Roads	Class II, III, or IV Roads - not useable in the summer months with a two-wheel drive vehicle. Winter Roads
Life of Road	Long Term Average over 20 years	Long Term 20 years Average	Medium Term Average 10 years	Short Term Generally less than 2 years	Depends on location Winter use only
Maintenance	High requirements	Fairly high requirements	Low requirements	Low to nil after construction	None - no grade nil to limited ditching
Maximum Right-of-way Total Width Level Ground	150 feet	132 feet	100 feet	66 feet	100 feet except for Class IV where 66 feet
Brush Disposal	Cleared to mineral soil 25 feet on each side of the running surface measured from the outside edge of the shoulder. Ditch to be kept free of debris. Balance of right-of-way to be cleared of all woody debris except stumps left in the ground. Accumulated debris to be disposed of by burning. Burying of unburned residue in approved locations as stipulated in the Forest Protection Regulations.	Same as for Class I	Cleared to mineral soil 15 feet on each side of the running surface measured from the outside edge of the shoulder. Ditch to be kept free of debris. Where traversing cut areas, balance of right-of-way to be scarified so that woody debris in the right-of-way is of no greater hazard than in the adjacent cut. Between cut blocks right-of-way to be cleared of all woody debris except stumps left in the ground.	Debris to be scarified within two years of construction of the road.	Debris to be spread and crushed to lie flat on the ground on both sides of the running surface and to be confined within the right-of-way. No leaning trees or windrows against the surrounding timber.

NORTH WESTERN PULP & POWER ROAD STANDARD GUIDELINES
SPECIFICATIONS APPLY ON LEVEL GROUND

	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V
			- continued: Accumulated debris to be disposed of by burning. Burying of unburned residue in approved locations as stipulated in the Forest Protection Regulations.		
Cuts and Fill Slopes	Cuts - maximum slope of 1-1/2.1 Fills - maximum slope of 2.1 Erosion control measures on cuts or fills exceeding twenty feet in depth.	Same as for Class I	Cuts - maximum slope of 1-1/2.1 Fills - maximum slope of 1-1/2.1 Erosion control measures on cuts or fills exceeding twenty feet in depth.	Same as for Class I	Minimal
Revegetation	All bared surfaces except the running surface of the road. Seed mixture used for revegetation to be approved by the Director to ensure minimum fire hazard.	All bared surfaces except the running surface of the road. Seed mixtures used for revegetation to be approved by the Director to ensure minimum fire hazard.	All critical slopes, cuts and fills. Seed mixture to be approved by the Director.	All critical slopes, cuts and fills. Seed mixture to be approved by the Director.	All critical bared slopes. Seed mixture to be approved by the Director.

Maximum area to be bared to mineral soil on level ground - See attached formula.

APPENDIX II: Precipitation Data For Road Stream Crossings, 1975

Precipitation was measured in m.s.c. standard raingauges. Where two or more road crossings were in close proximity, a centrally located gauge was used to measure precipitation. Gauges were serviced as frequently as possible. Normally, observations were made in conjunction with sediment sampling and/or during or following the day of precipitation.

Precipitation For Road Stream Crossings MC0901, MC0902, 1975.

Month	Date	Precipitation - Inches
April	30	gauge installed
May	6	1.36
	13	.06
	16	.15
	21	.29
	23	.30
	26	.05
	27	.12
	28	nil
	29	nil
	30	.12
June	2	nil
	3	0.18
	4	nil
	6	.60
	10	nil
	17	.64
	24	.32
	26	.10
	28	2.21 (1.84 0940 hr, 0.37 1740 hr)
	29	.01
July	8	0.08
	15	.38
	22	.04
	25	trace
	29	.08
	31	.01
August	5	0.21
	7	.15
	11	.34
	12	nil
	19	.21
	26	.53

Precipitation For Road Stream Crossings MC0606, MC0607, 1975.

Month	Date	Precipitation - Inches
May	14	gauge installed
	16	0.06
	21	0.32
	23	.11
	26	.08
	27	.21
	28	.02

	29	nil
	30	.10
June	2	nil
	3	0.15
	4	nil
	6	.48
	17	1.18 (accumulated June 6)
	26	.88
	28	1.04
	29	.05
July	8	0.04
	15	.30
	22	.05
	25	.03
	28	.09
August	5	0.20
	7	.13
	11	.33
	19	.22
	22	.32
	26	.40

Precipitation For Road Stream Crossing MC0618, 1975.

Month	Day	Precipitation - Inches
May	14	gauge installed
	16	0.08
	21	.28
	23	.29
	26	.12
	27	.26
	29	.02
	30	.10
June	2	nil
	3	.15
	4	nil
	6	.43
	26	2.14 (accumulated June 6)
	28	1.10
	29	.04
July	8	0.04
	15	.62
	22	.03
	25	.02
	28	.06
August	5	0.29
	7	.19
	11	.34
	20	.23
	22	.27
	26	.18

Precipitation For Road Stream Crossings ER1, ER2, ER3, 1975

Month	Date	Precipitation - Inches
May	14	gauge installed
	16	0.10
	21	.40
	27	.44
	28	.06
	29	nil
June	3	0.35
	4	nil
	5	nil
	26	2.17 (accumulated June 5)
	29	1.26
July	8	0.11
	15	1.28
	24	.54
	29	.16
August	5	0.38
	11	.29
	18	.20
	22	.33
	26	.11

Precipitation For Road Strea Crossing ER5, 1975.

Month	Date	Precipitation - Inches
May	14	gauge installed
	21	0.19 (accumulated May 14)
	27	.78
	28	.03
	29	nil
June	3	0.54
	4	nil
	5	nil
	25	1.76
	26	.06
	29	1.44
July	8	0.04
	15	1.08
	18	.36
	29	.25
August	5	0.33
	7	.02
	15	.32
	18	.45
	22	.15
	26	.20

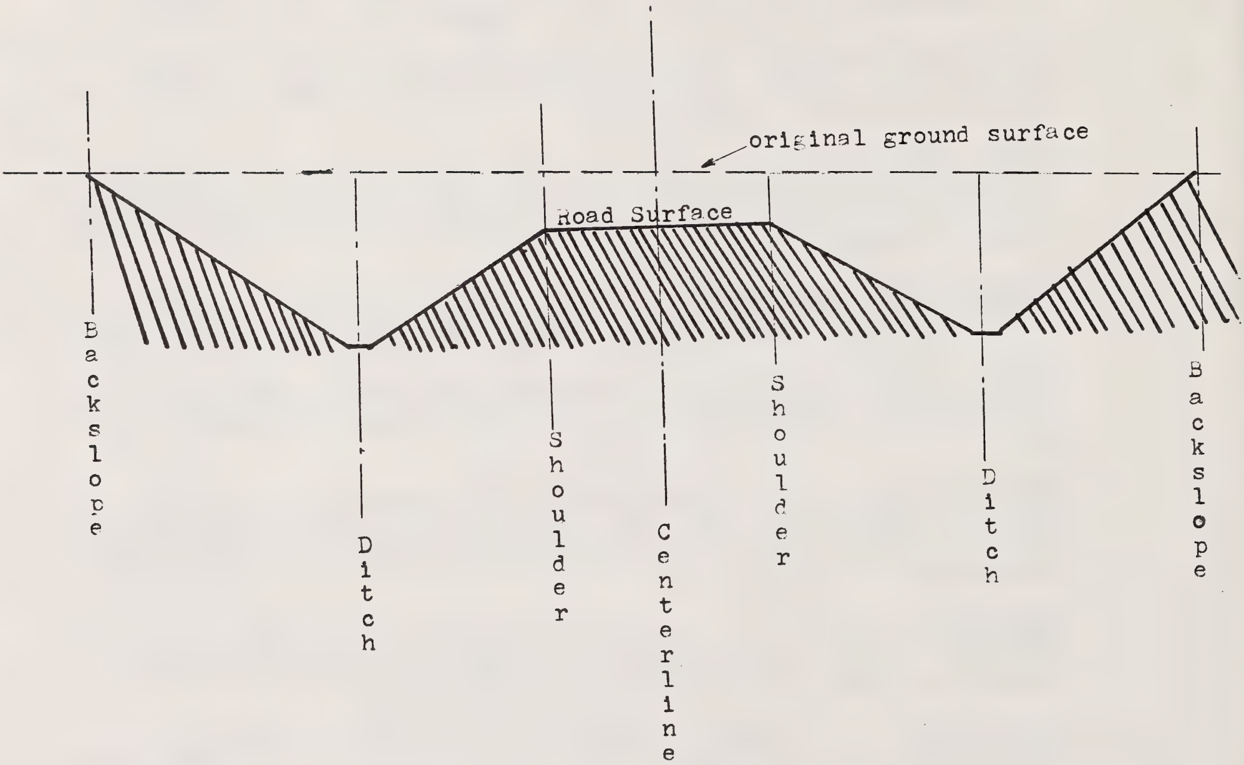
APPENDIX III: Descriptions of Road-Stream Crossings

Descriptions of Road-Stream Crossings.

The items included in each road-crossing description are:

- Location by section, township and range.
- Area treated at each road-stream crossing in hectares. Treatment areas extended upslope from each streambank to the topographic divide or the first major break in slope.
- Per cents of the treatment area existing in road surface, road shoulder and backslopes.
- Road description indicating class of road, type of crossing, depth of fill over the culvert, total road length in the treatment area, and road gradient approaches to the stream.
- Stream channel and Streamflow shows mean summer flow in m^3/sec, maximum flows observed during the study and other times is data was available, stream width and depth at the current metering site, and stream order by Strahler's method.
- Sediment flows shown are mean sediment concentrations mg/l and sediment production in kg/ha/day for total summer flow season and storm periods.
- Seasonal plots of sediment concentrations and sediment production. Maximum events are indicated by date, and maximum values in either mg/l or kg/day.
- Plane view map of each crossing showing size and shape of treatment area and bare eroding soil areas. The maps were drawn on an x-y axis with a Hewlett-Packard plotter. Note that scales for distance on the ordinate and abscissa are not equal.
- Sketches of each half of a crossing, obtained by orthographic projection are shown to illustrate relative slope differences at a site and the location and distribution of bare eroding soil areas.
- Photographs of the crossings and specific photo plots to show the treatments and rate of revegetation.

A level survey of each road-stream crossing was done. Elevations were determined at road centerline, shoulders, ditch and top of backslope at intervals of 15-30 m for the length of the treated area.



Road Crossing - MC0901 - McPherson Creek
Location: Section 15 NW¼, Township 51, Range 24, W5M

Area Treated: 1.16 ha

29% road surface
36% road shoulders
35% backslope

Road Description:

second class road	
culvert crossing	
depth of fill over culvert	3.4 m
road distance	305.0 m
road gradient approaches	9%, 3%

Stream Description:

mean summer flow	0.044 m^3/sec
maximum flow	
1973	0.286 m^3/sec
1975	0.130 m^3/sec
stream width-depth	1.5 - 0.6 m
stream order	1 st

Sediment Flows:

1975	
Sediment Concentration	
mean seasonal	
upstream	13.0 mg/1
downstream	37.0 mg/1
storms	
June 28-30, 1975	
upstream	18.0 mg/1
downstream	110.0 mg/1
Sediment Production	
seasonal	267.0 kg/ha/day
storm	
June 28-30, 1975	1000.0 kg/ha/day

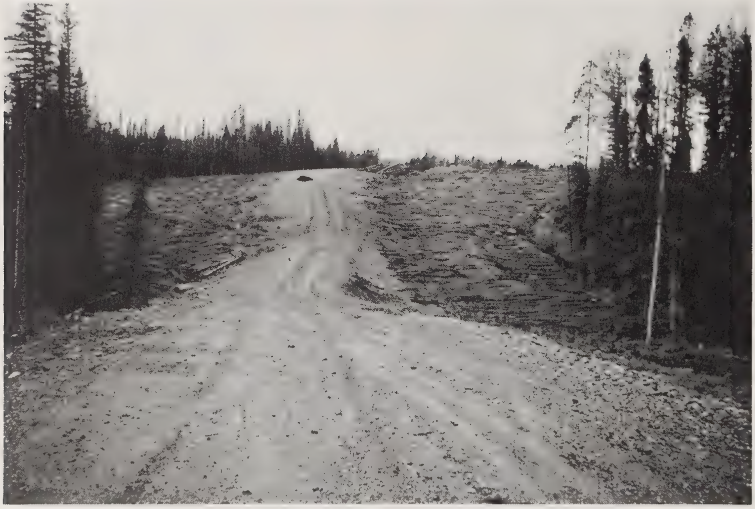


Figure 7 MC0901 - West Half June 1975.

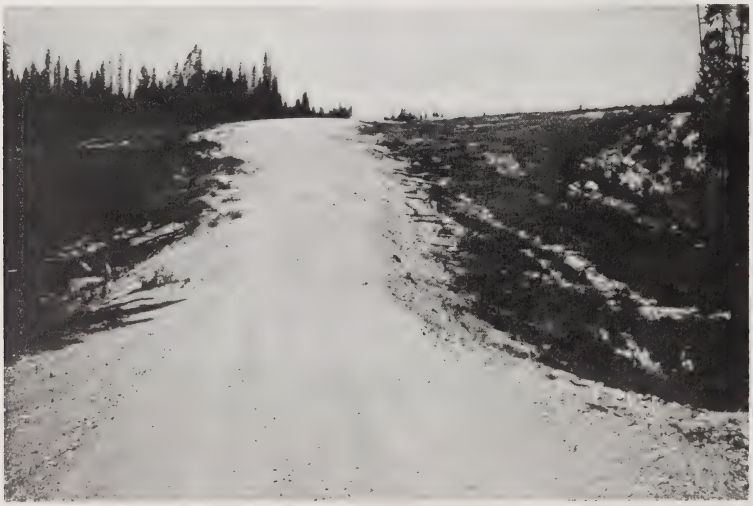


Figure 8. MC0901 - West Half - July 1976.

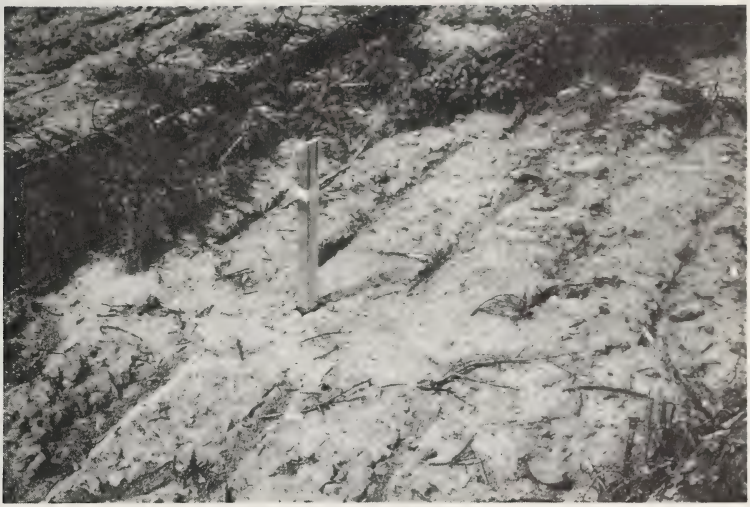


Figure 9. MC0901 - Photo Plot - 1975.

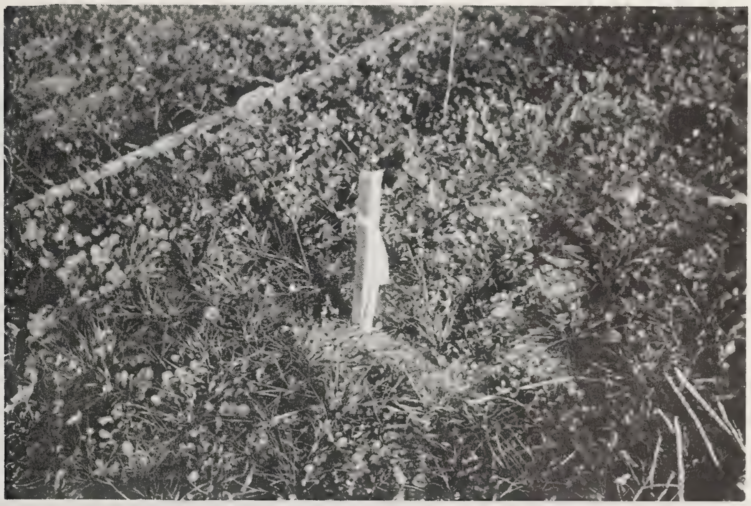


Figure 10. MC0901 - Photo Plot - 1976.

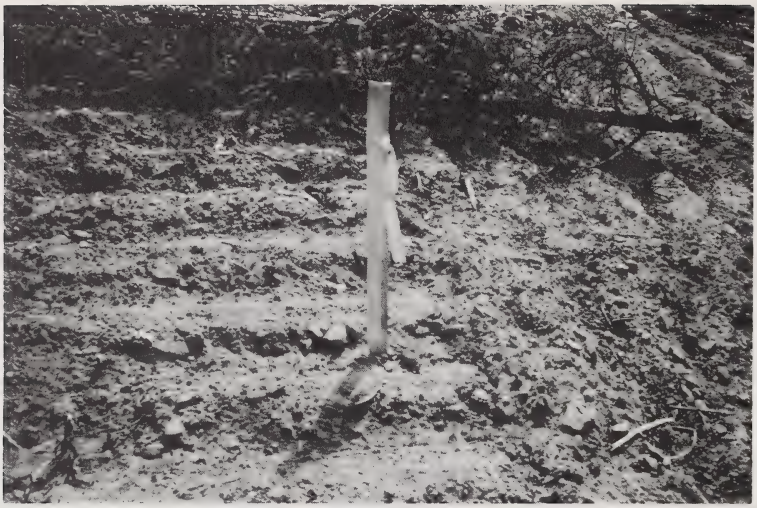


Figure 11. MC0901 - Photo Plot - 1975

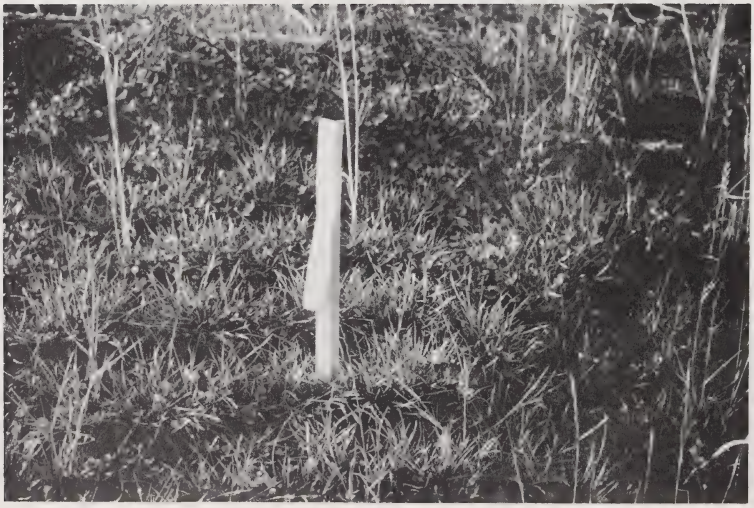


Figure 12. MC0901 - Photo Plot - 1976.

Figure 13
Road Stream Crossing MC0901

Sediment Flows 1975: May 15 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

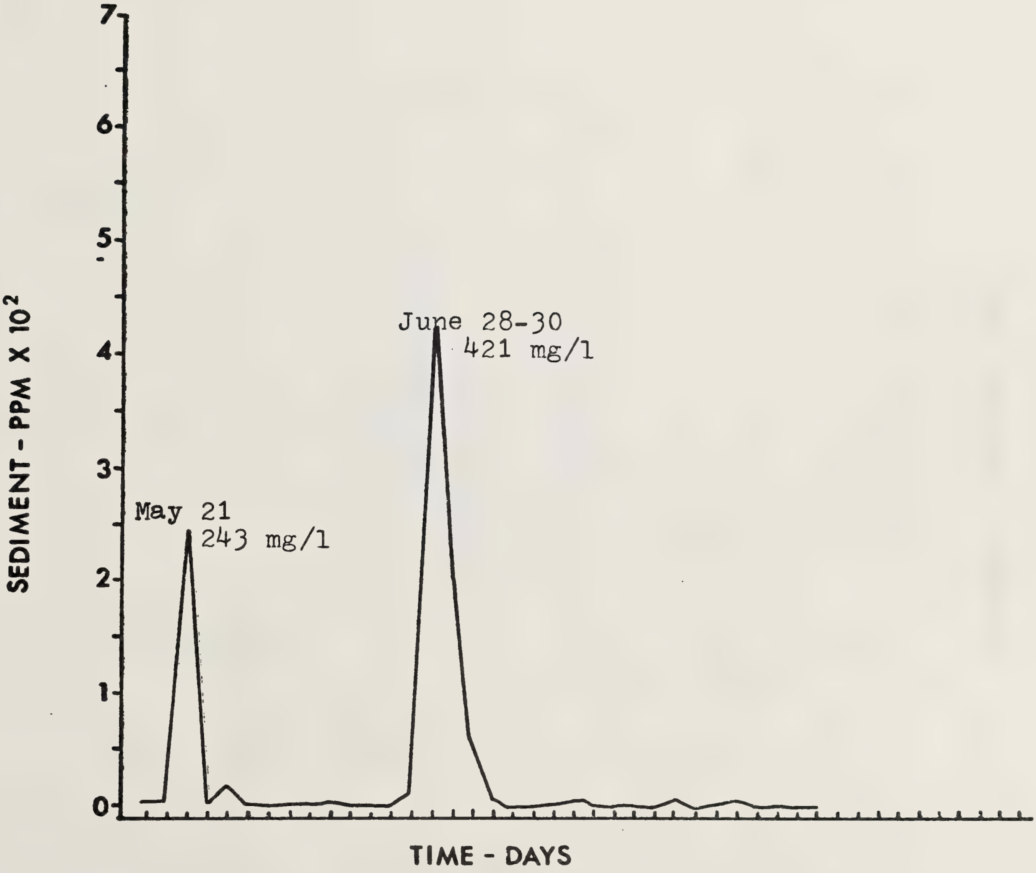


Figure 14

Road Stream Crossing MC0901

Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

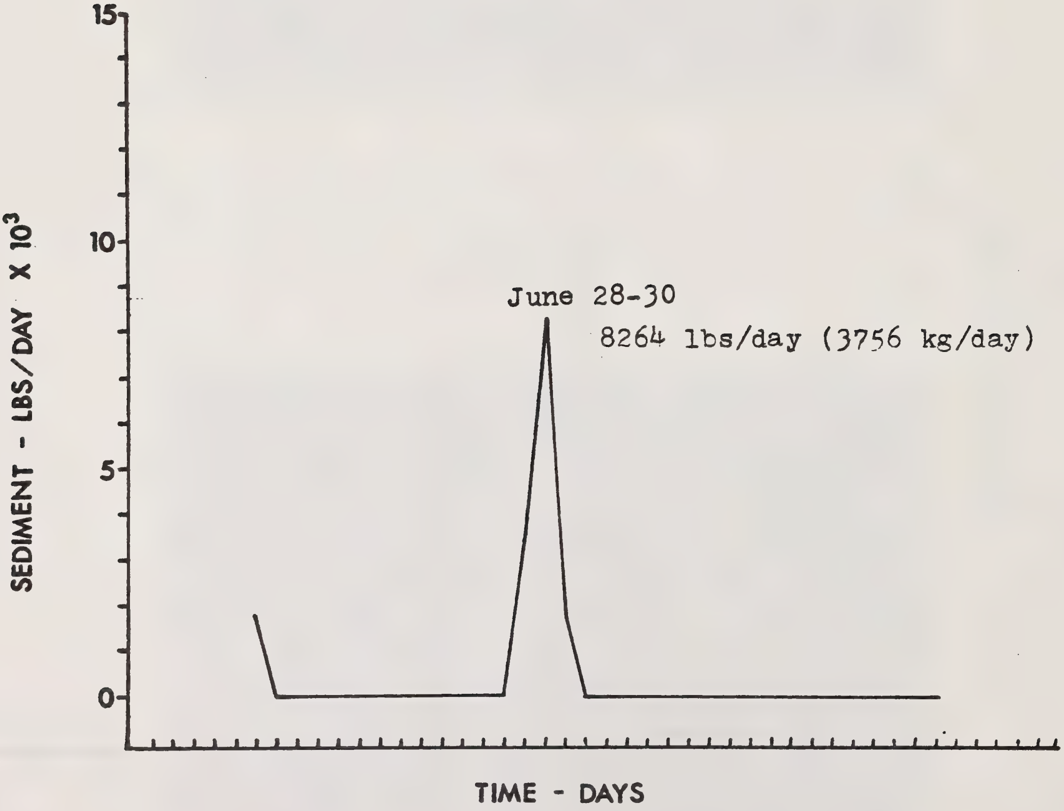


Figure 15

Plane view map of MC0901, August 1976, showing bare soil areas.

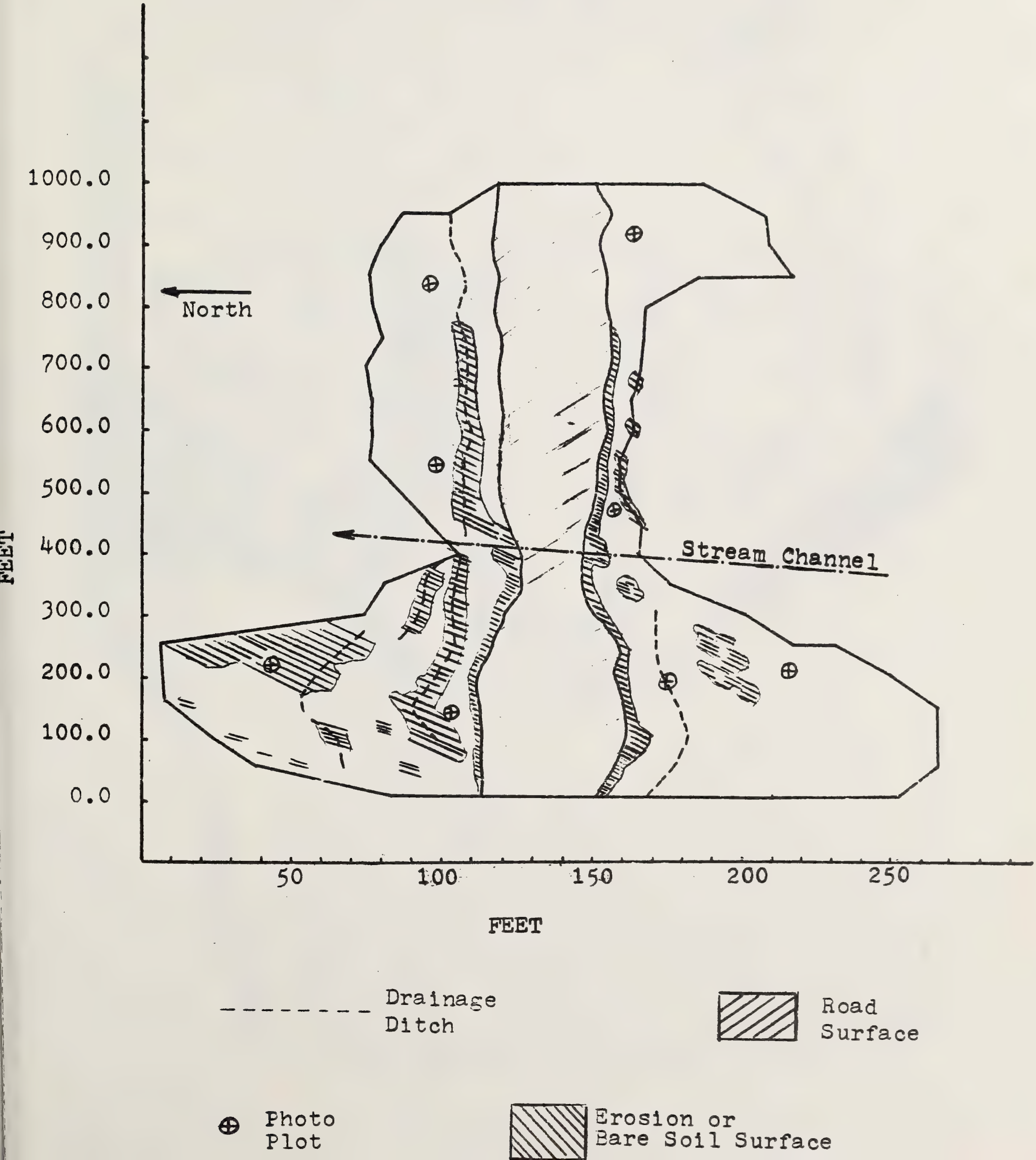


Figure 16

Road Crossing MC0901 - West Half

Bare soil areas as of 1976 shown by cross-hatching

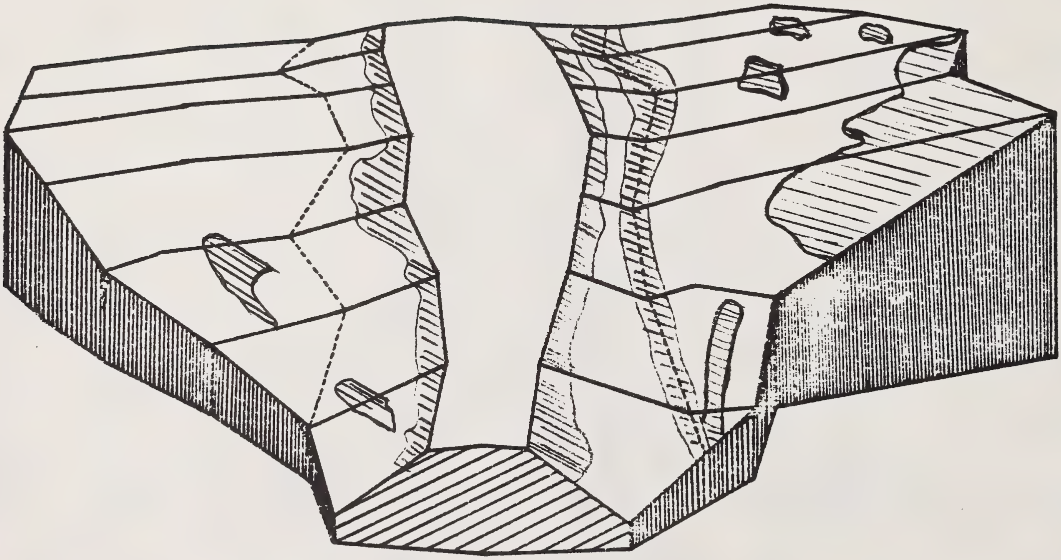
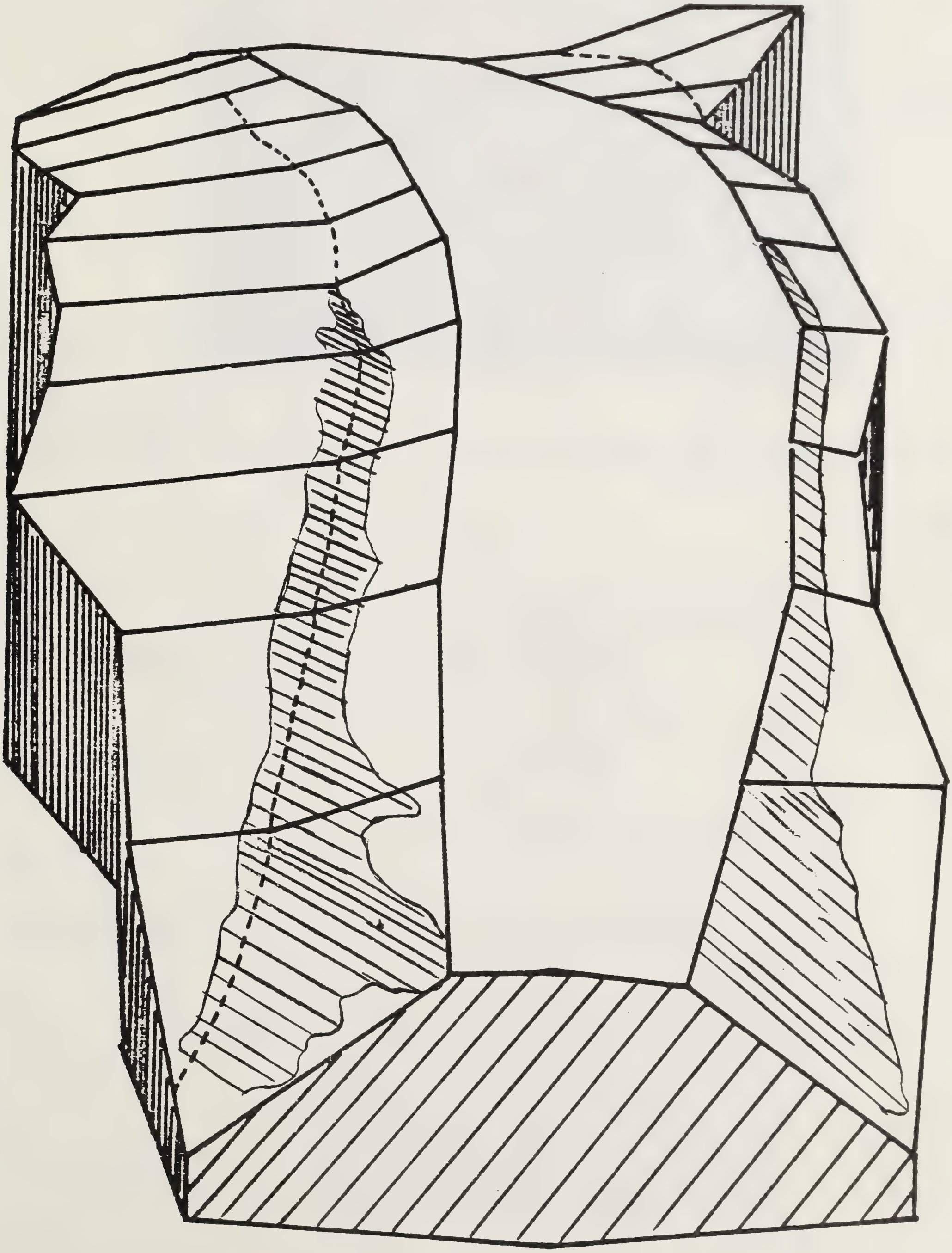


Figure 17

Road Crossing MC0901 - East Half

Bare soil areas as of 1976 shown by cross-hatching.



Road Crossings - MC0902 - McPherson Creek
Location: Section 10, Township 51, Range 24

Area Treated: 0.45 ha

29% road surface
36% road shoulder
35% backslope

Road Description:

second class road	
culvert - diameter crossing	
depth of fill over culvert	3.7 m
road distance	168.0 m
road gradient approaches	7%, 1%

Stream Channel and Streamflow :

mean summer flow	0.047 m^3/sec
maximum flow	
1973	0.302 m^3/sec
1975	0.532 m^3/sec
stream width-depth	1.2 - 0.4 m
stream order	1 st

Sediment Flows:

1975	
Sediment Concentration	
mean seasonal	
upstream	13.0 mg/1
downstream	27.0 mg/1
storms	
June 28-30, 1975	
upstream	9.0 mg/1
downstream	117.0 mg/1
Sediment Production	
seasonal	1393 kg/ha/day
storm	
June 28-30, 1975	5206 kg/ha/day

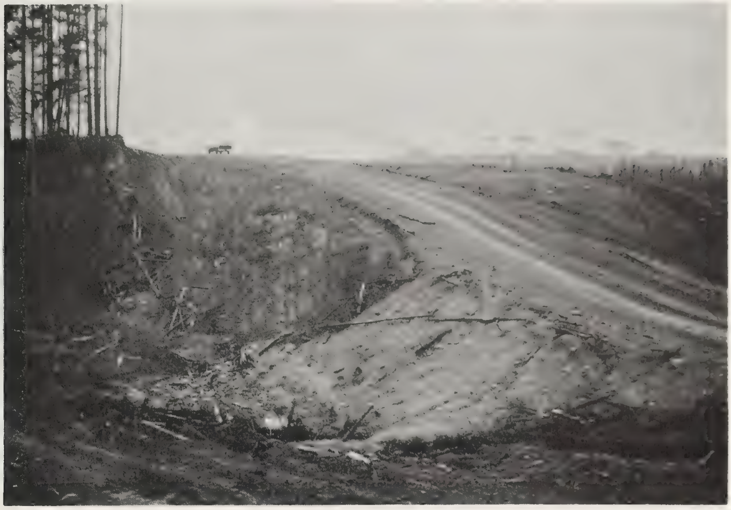


Figure 18. MC0902 - Fill Section Upstream Side of Road. Soil Condition Following Grass Sowing and First Rainstorm - 1975.

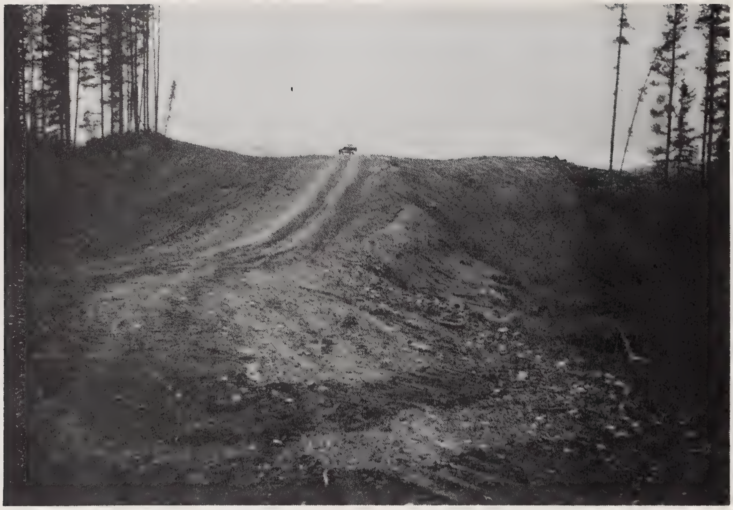


Figure 19. MC0902 - West Half - 1975 - Following Site Preparation and Grass Sowing.

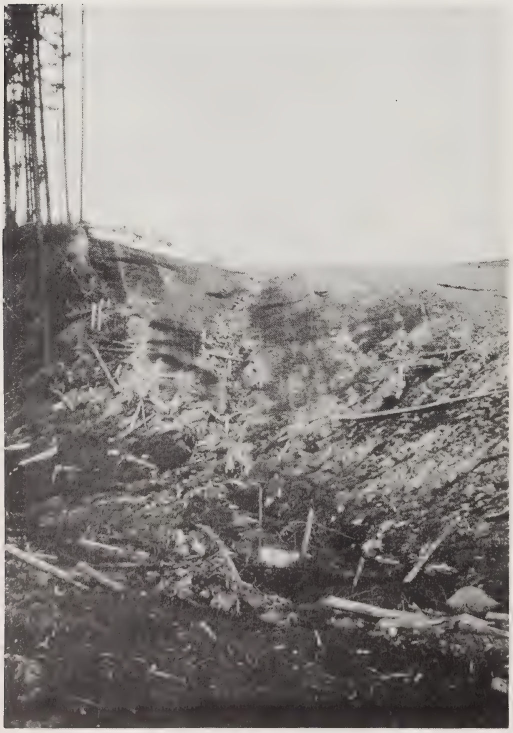


Figure 20. MC0902 - SW Quadrant - 1976. Erosion and Gully Development From Road Side Drainage Ditch.

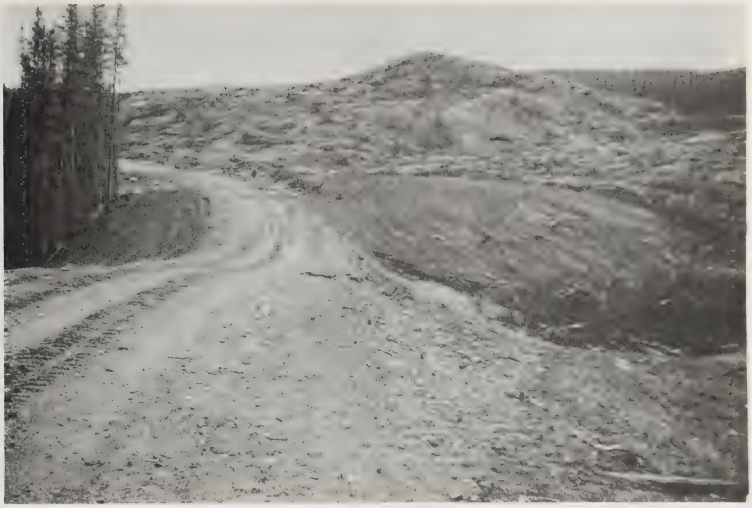


Figure 21. MC0902 - East Half - June 1976.

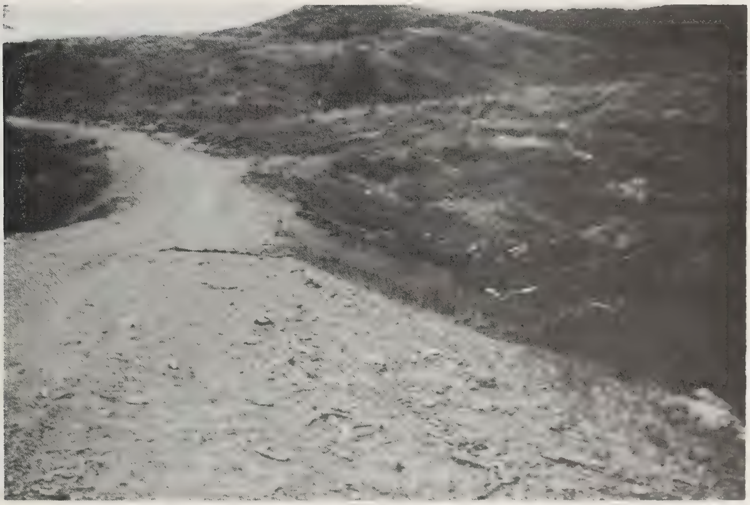


Figure 22. MC0902 - East Half - June 1975.

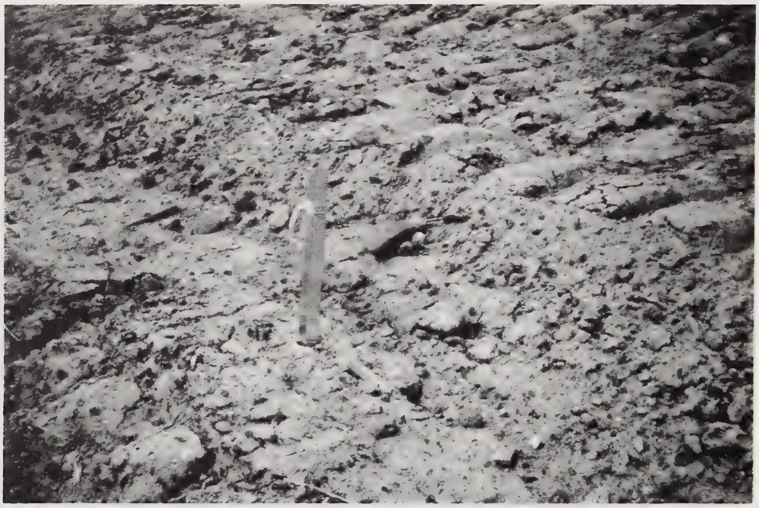


Figure 23. MC0902 - Photo Plot Following Grass Sowing - 1975.

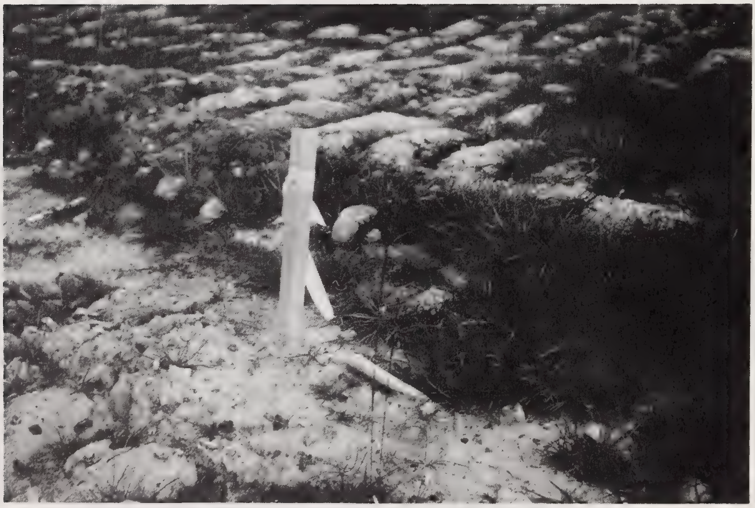


Figure 24. MC0902 - Photo Plot - 1976. Note Establishment of Grass in Tractor Tracks.

Figure 25

Road Stream Crossing MC0902

Sediment Flows 1975: May 15 - August 26

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

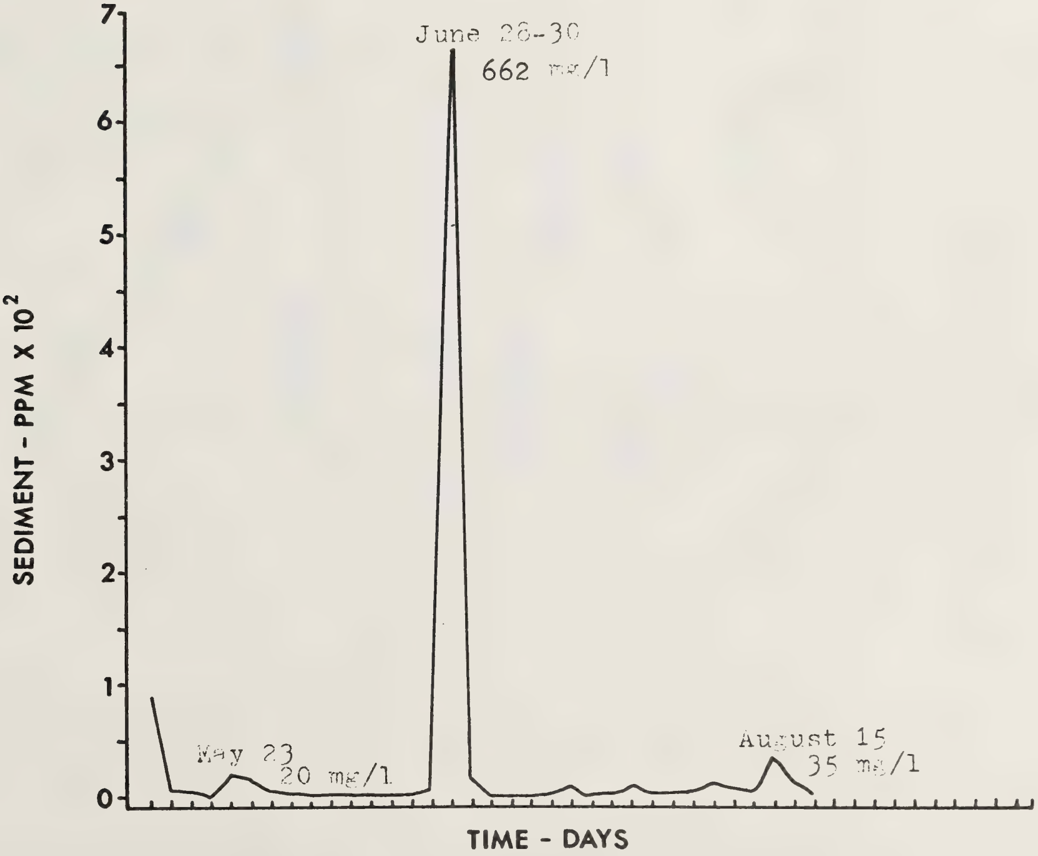


Figure 26

Road Stream Crossing MC0902

Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

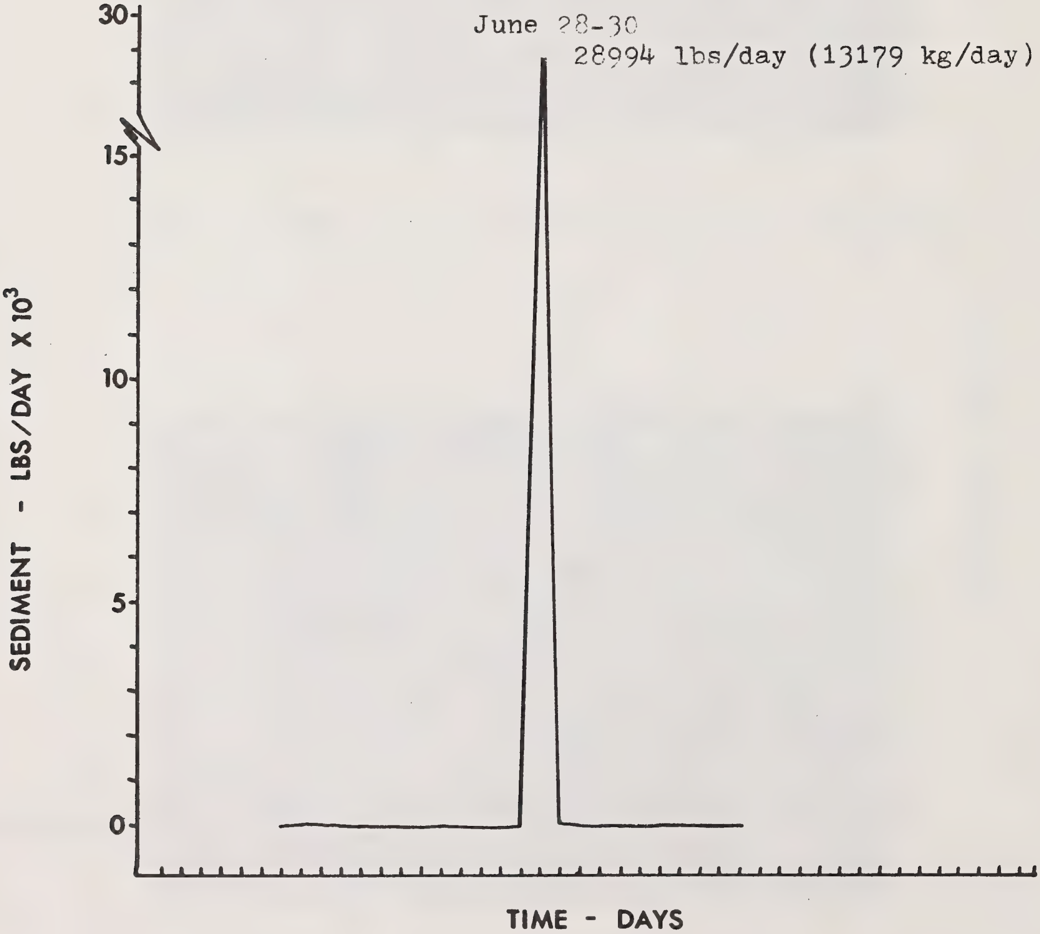


Figure 27

Plane view map of MC0902, August 1976, showing bare soil areas.

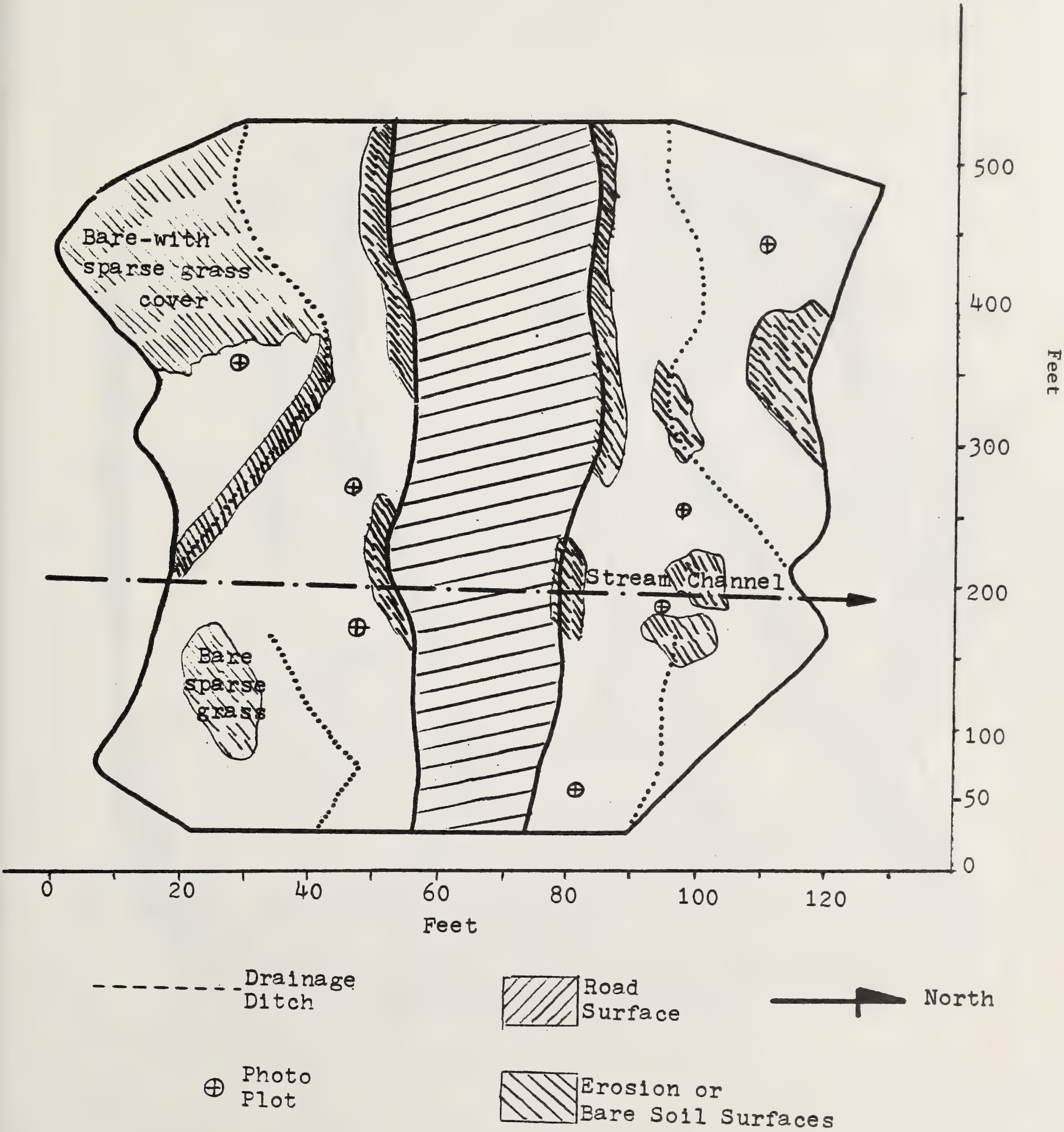


Figure 28

Road Crossing MC0902 - West Half

Bare soil areas as of 1976 shown by cross-hatching

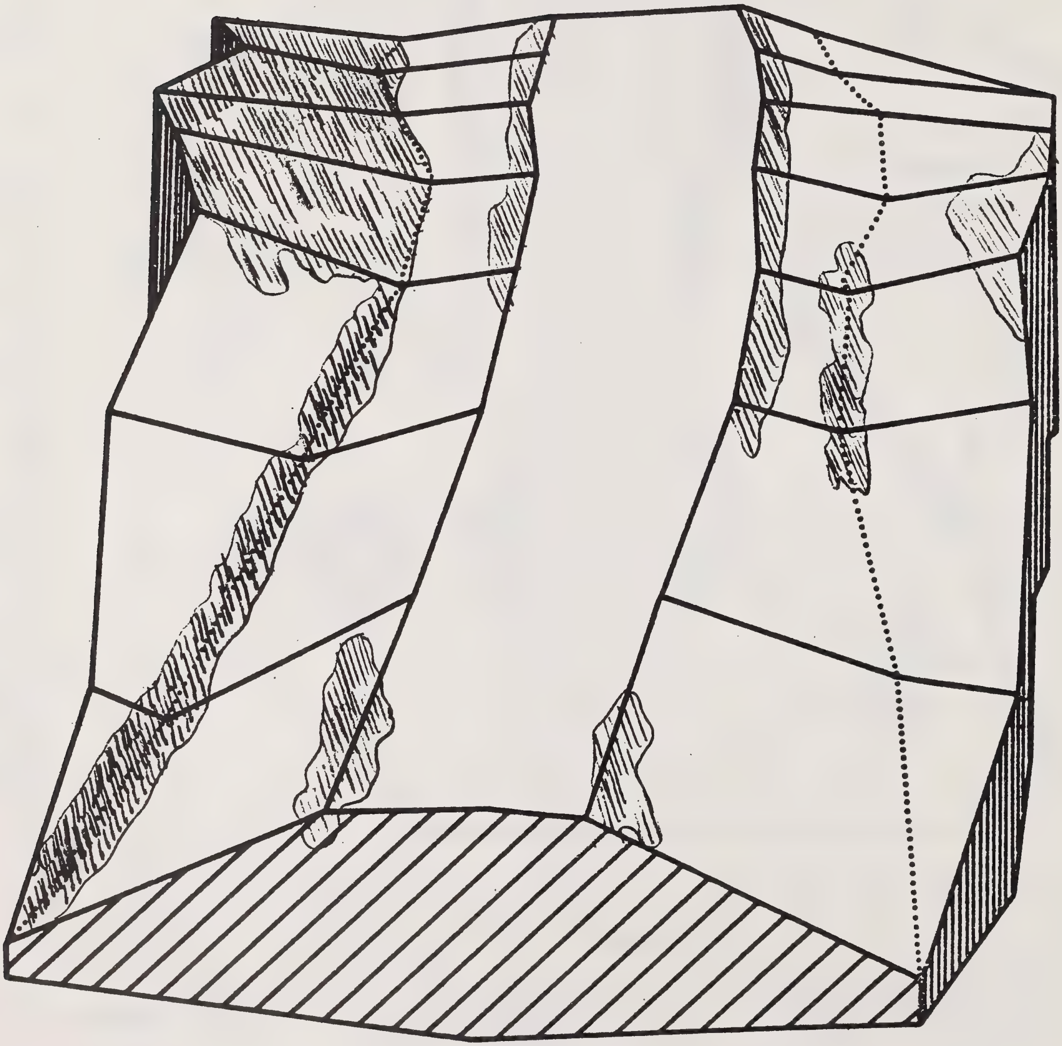
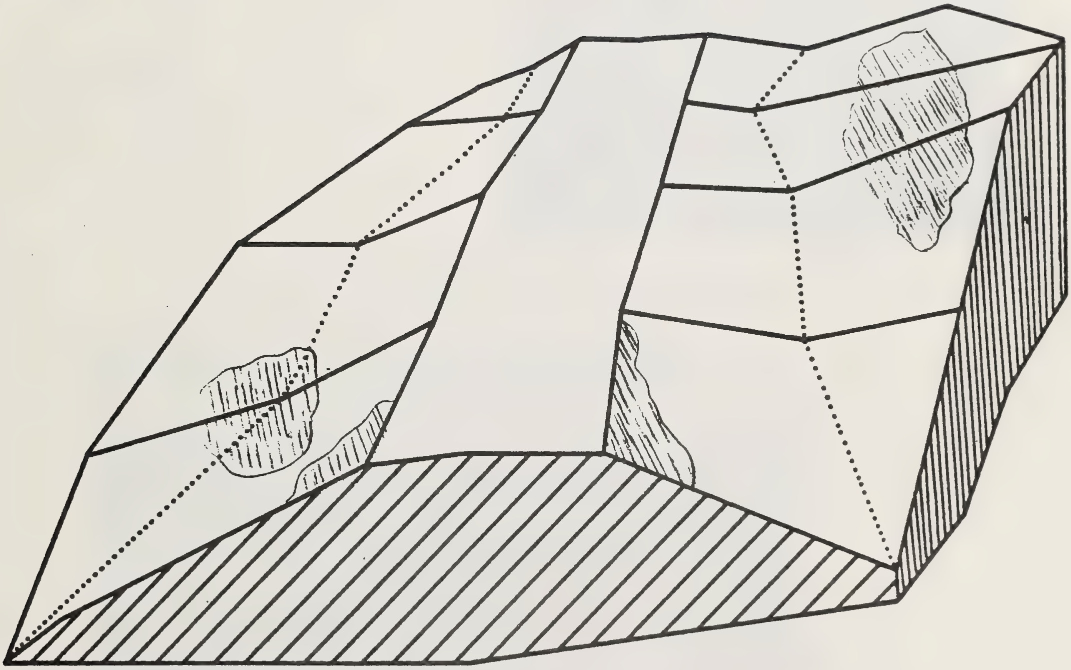


Figure 29

Road Crossing MC0902 - East Half

Bare soil areas as of 1976 shown by cross-hatching



Road Crossings - MC0606 - Felton Creek
Location: Section 19, Township 49, Range 22

Area Treated: 0.923 ha

22% road surface
30% road shoulder
48% backslope

Road Description:

second class road	
culvert - diameter crossing	
depth of fill over culvert	1.82 m
road distance	457.0 m
road gradient approaches	7%, 6%

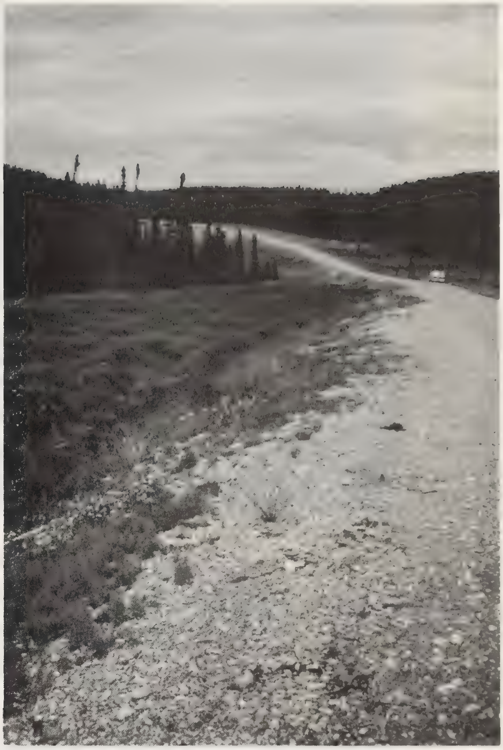
Stream Channel and Streamflow :

mean summer flow	0.053 m^3/sec
maximum flow	
1973	0.209 m^3/sec
1975	0.108 m^3/sec
stream width-depth	1.2 - 1.2 m
stream order	2 nd

Sediment Flows :

1975	
Sediment Concentration	
mean seasonal	
upstream	12.0
downstream	9.0
storms	
June 28-30, 1975	
upstream	10.0
downstream	18.0
Sediment Production	
seasonal	6.40 kg/ha/day
storm	
June 28-30, 1975	49.2 kg/ha/day

Figure 30. MC0606 - West Side of Road Looking Towards Felton Creek - 1976. Note Lush Growth of Clover. Logging Debris not Visible.



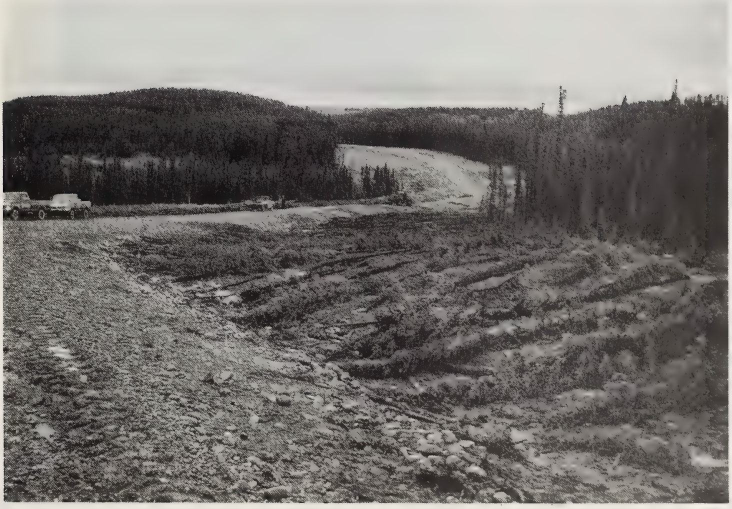


Figure 31. MC0606 - East Side of Road in Foreground Being Treated with Brush Mulch - 1975.

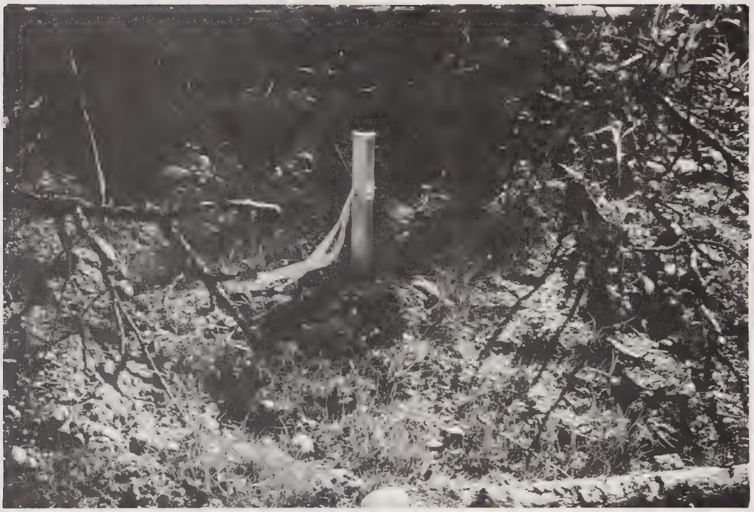


Figure 32. MC0606 - Photo Plot Following Treatment - 1975. Note Newly Established Grass.

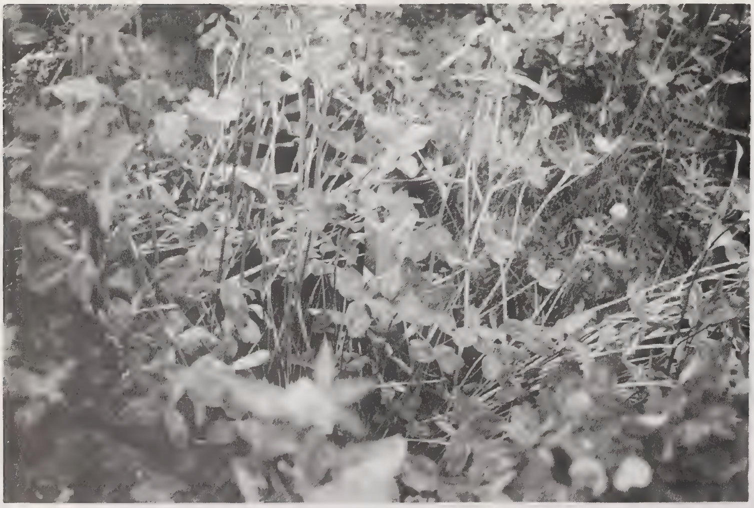


Figure 33. MC0606 - Photo Plot in 1976 with Heavy Clover Cover.

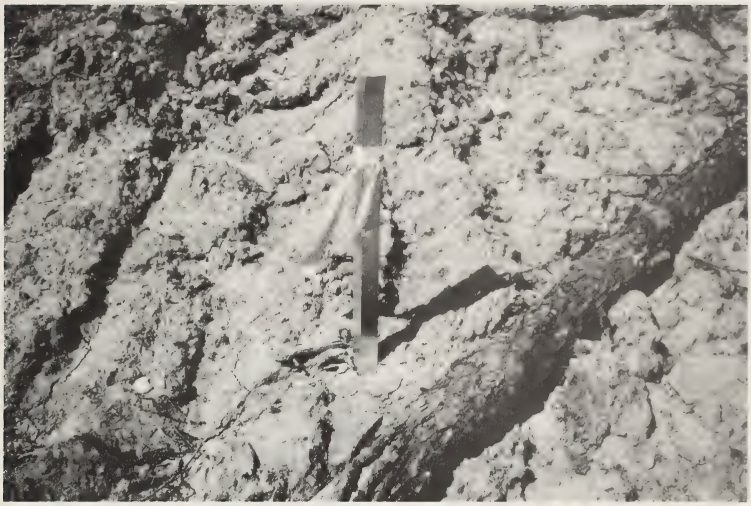


Figure 34. MC0606 - Photo Plot Following Treatment of Grass and Brush Mulch - 1975.

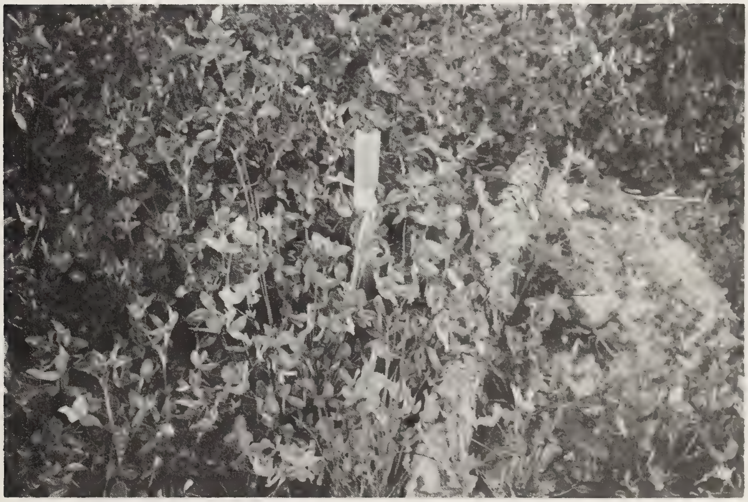


Figure 35. MC0606 - Photo Plot in 1976.

Figure 36

Road Stream Crossing MC0606

Sediment Flows 1975: May 14 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

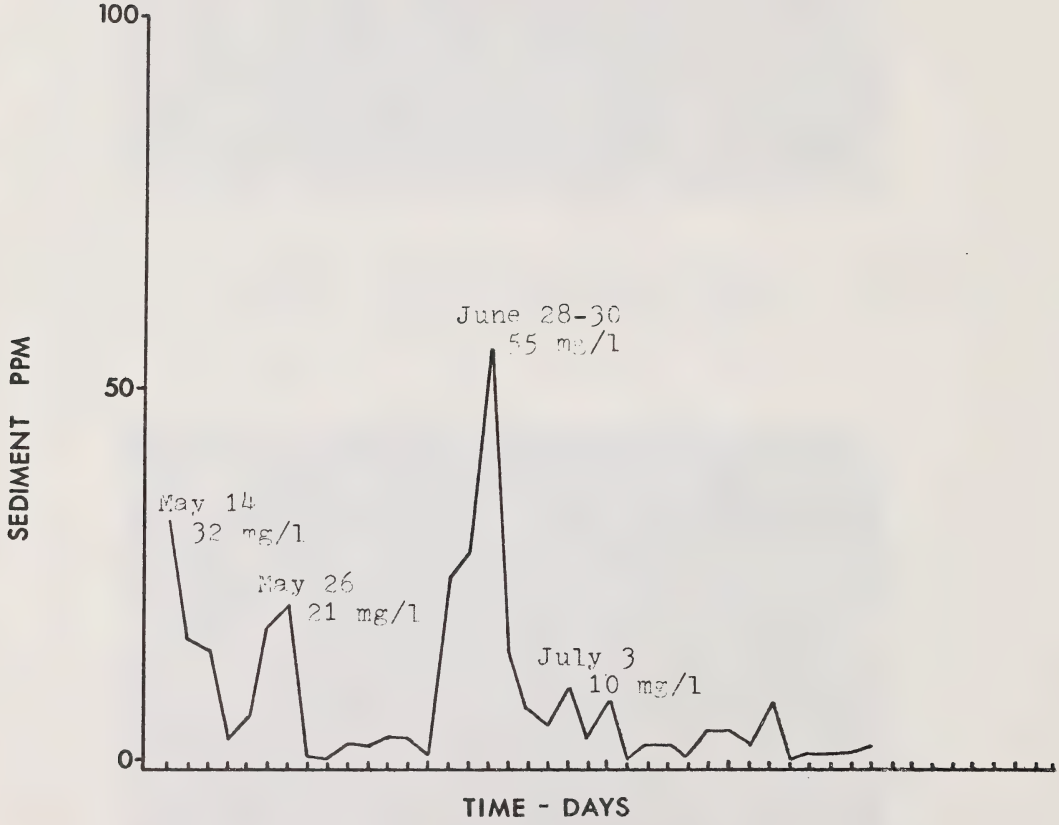


Figure 37

Road Stream Crossing MC0606

Sediment Production 1975: May 14 - August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

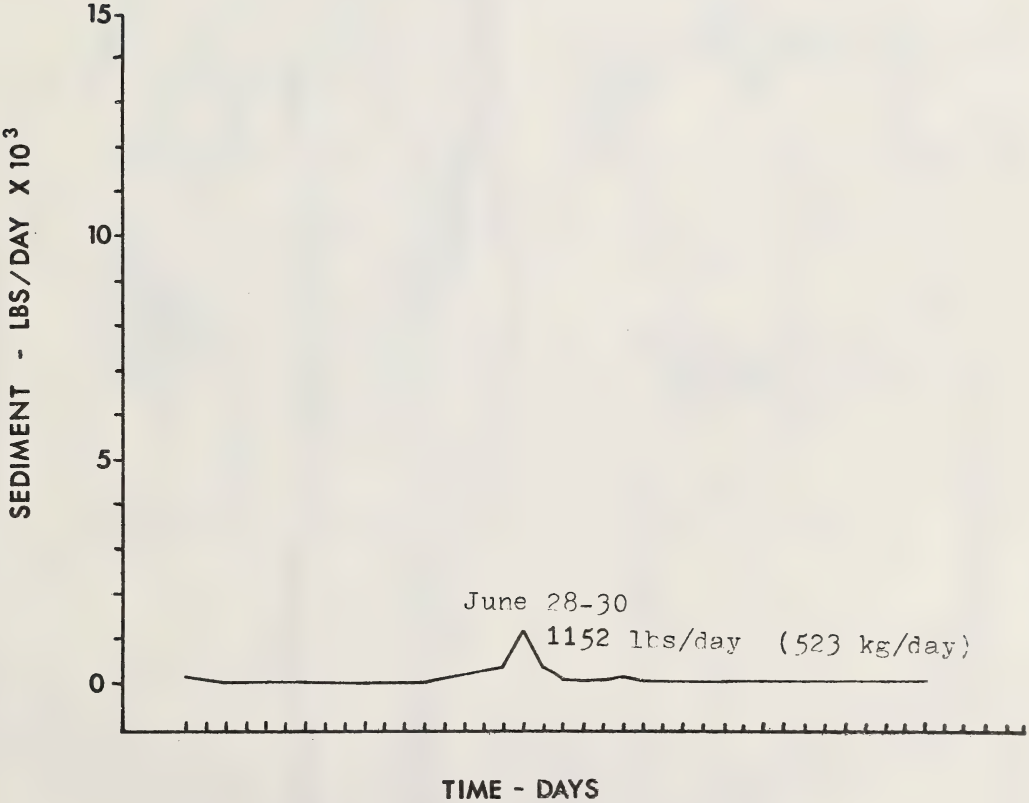


Figure 38
Plane view map of MC0606, South half, August 1976, showing bare soil areas.

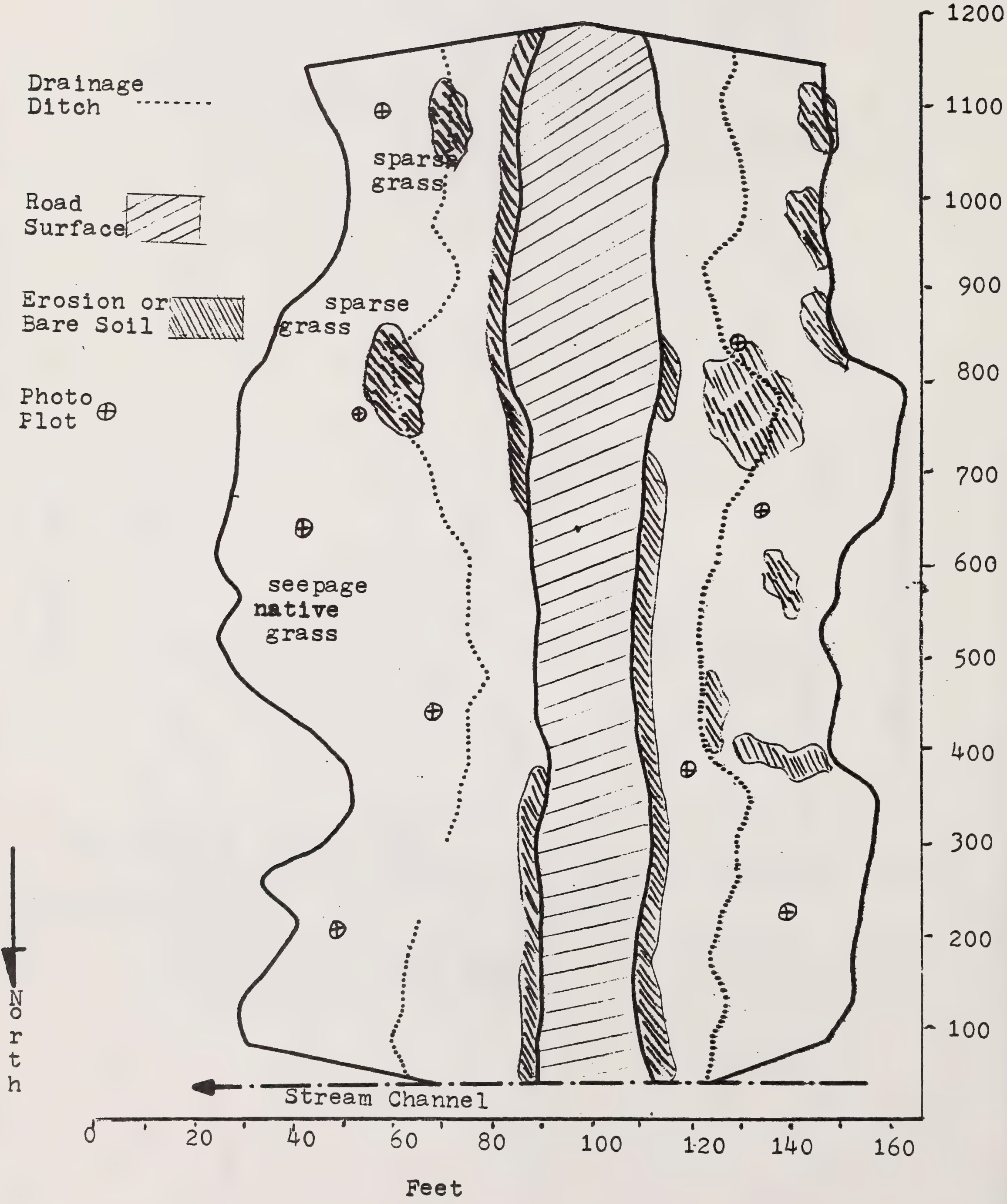
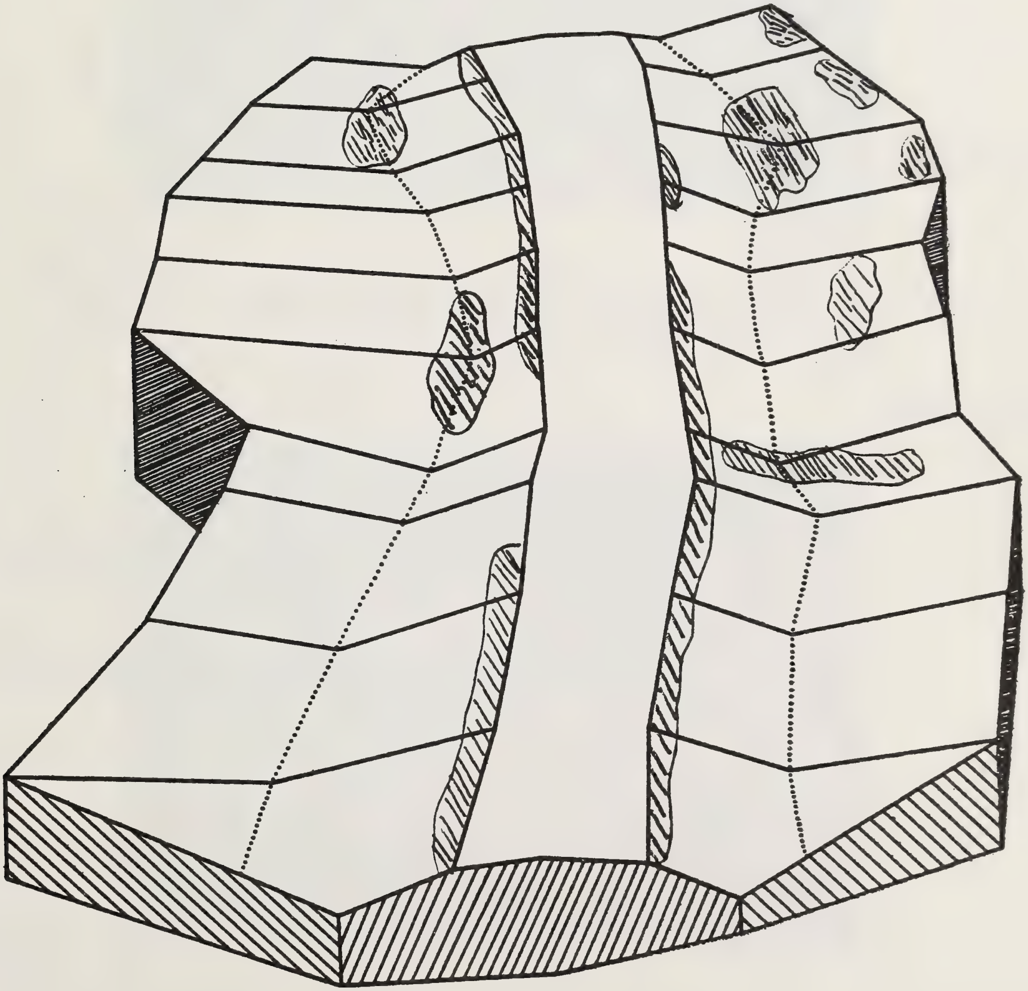


Figure 39

Road Crossing MC0606 - South Half

Bare soil areas as of 1976 shown by cross-hatching



Road Crossing - MC0607 - Felton Creek
Location: Section 17, Township 49, Range 22

Area Treated: 2.16 ha

20% road surface
31% road shoulder
49% backslope

Road Description:

second class road	
culvert - diameter crossing	
depth of fill over culvert	2.44 m
road distance	608.0 m
road gradient approaches	8%, 3%

Stream Channel and Streamflow:

mean summer flow	0.044 m^3/sec
maximum flow	
1973	0.343 m^3/sec
1975	0.224 m^3/sec
stream width-depth	0.9 - 0.5 m
stream order	1 st

Sediment Flows:

1975	
Sediment Concentration	
mean seasonal	
upstream	20.0 kg/ha/day
downstream	59.0 kg/ha/day
storms	
June 28-30, 1975	
upstream	63.0 kg/ha/day
downstream	201.0 kg/ha/day
Sediment Production	
seasonal	13.24 kg/ha/day
storm	
June 28-30, 1975	135.2 kg/ha/day

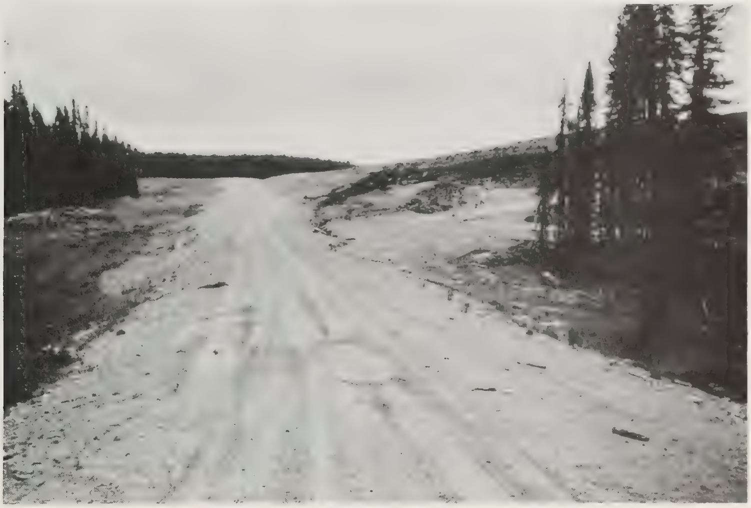


Figure 40. MC0607 - South Half - 1976. Uphill Side of Road Serious Source of Bank Slumping, Erosion and Sediment.

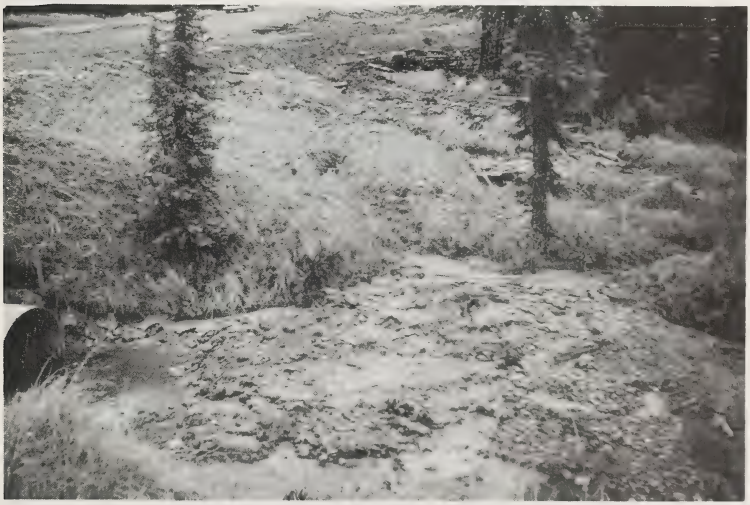


Figure 41. MC0607 - Culvert Inlet Showing Accumulation of Sediments Orginiating From Upper SW Quadrant of Road.

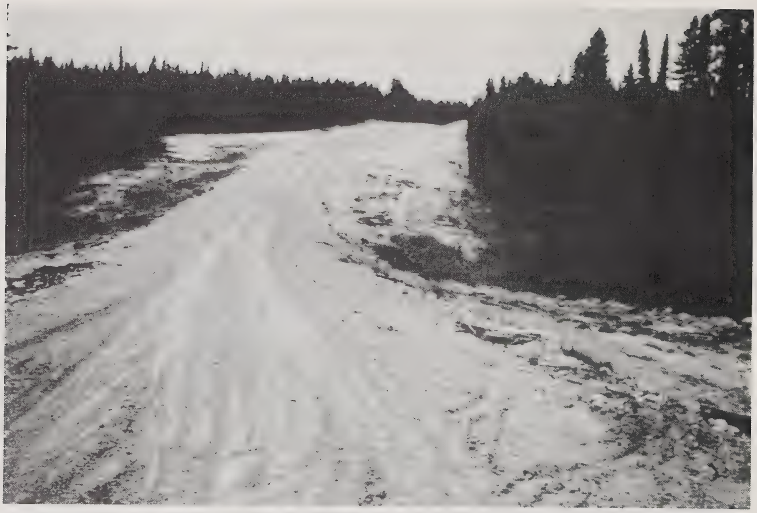


Figure 42. MC0607 - North Half of Road in July - 1975 Following Grass Sowing Treatment.

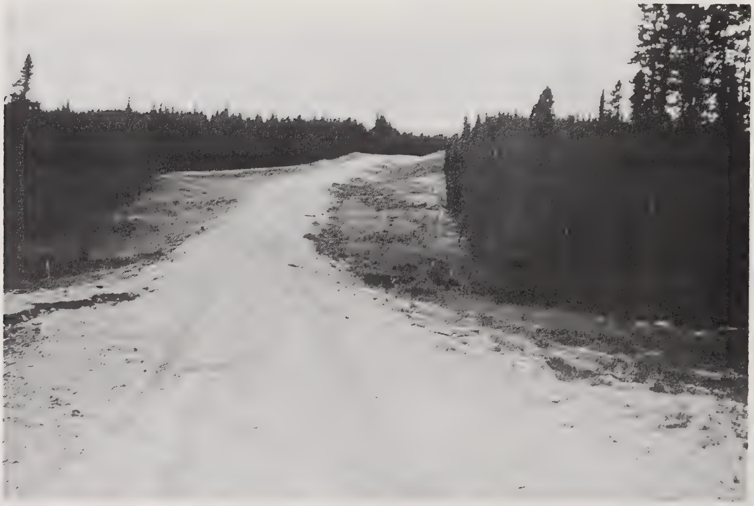


Figure 43. MC0607 - North Half of Road in June - 1976. Note Gully Development Orginating From Road Side Ditch in SW Quadrant (Left Lower Corner).

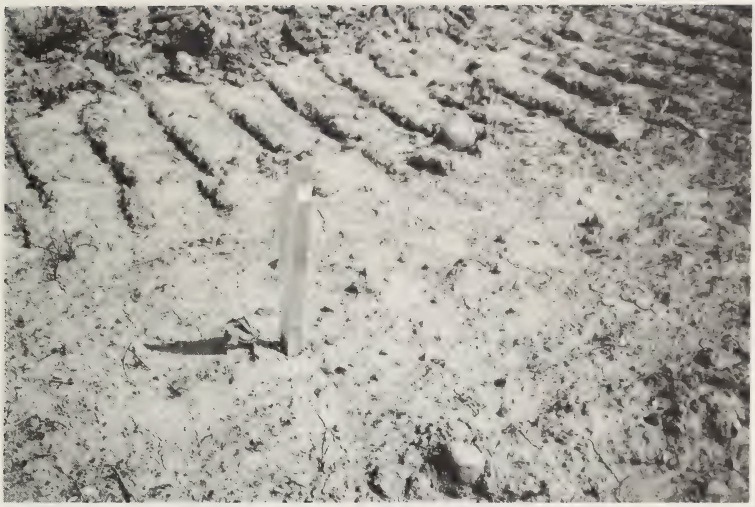


Figure 44. MC0607 - Photo Plot in 1975 Following Treatment Application.

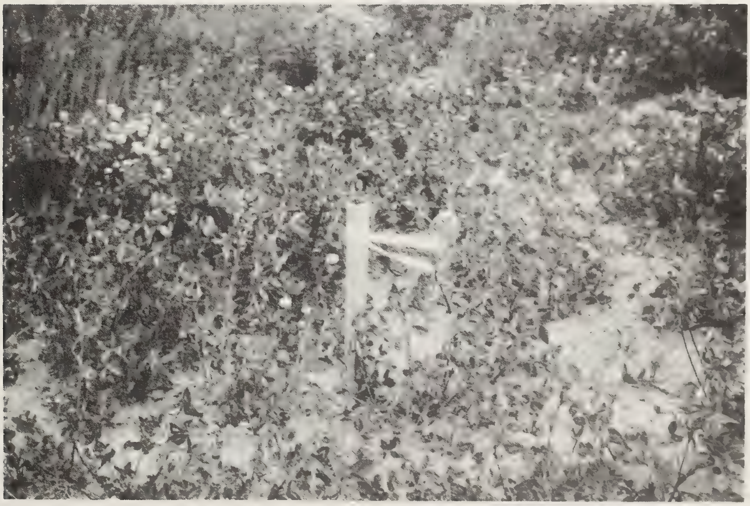


Figure 45. MC0607 - Photo Plot in 1976 With Grass-Clover Cover.

Figure 46

Road Stream Crossing MC0607

Sediment Flows 1975: May 15 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

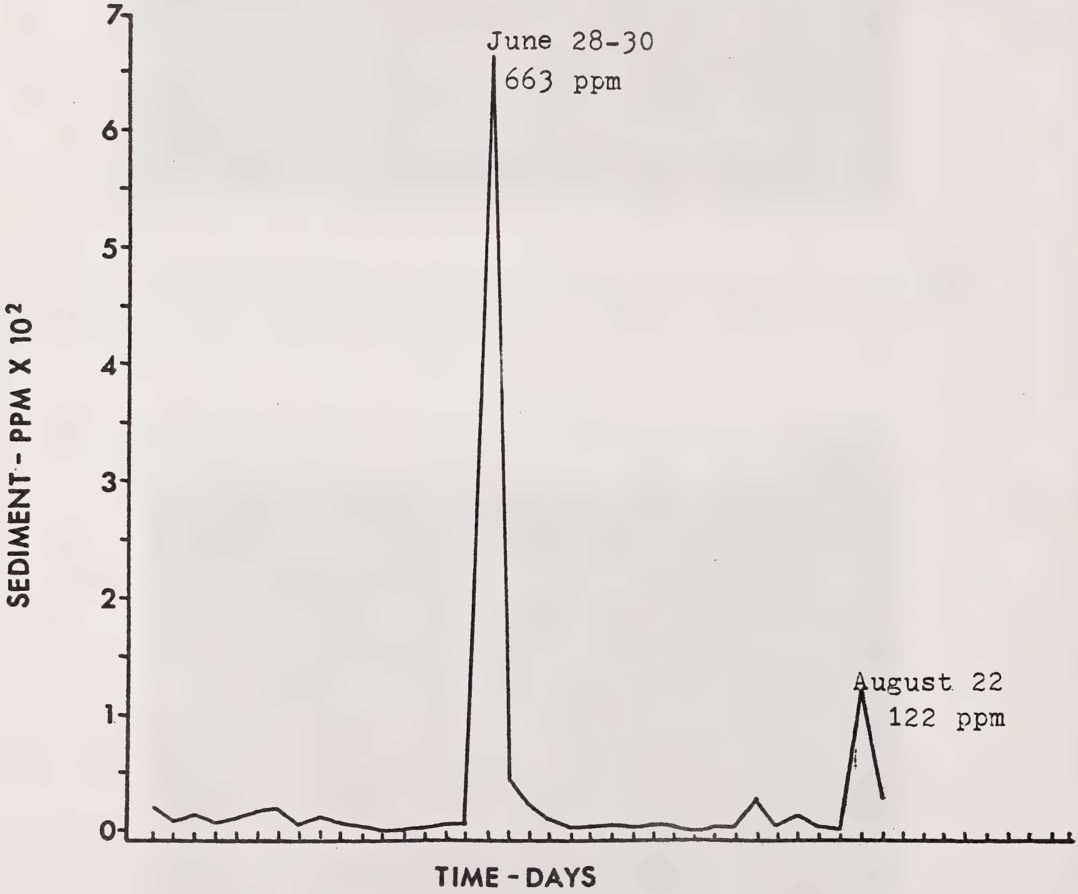


Figure 47

Road Stream Crossing MC0607
Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

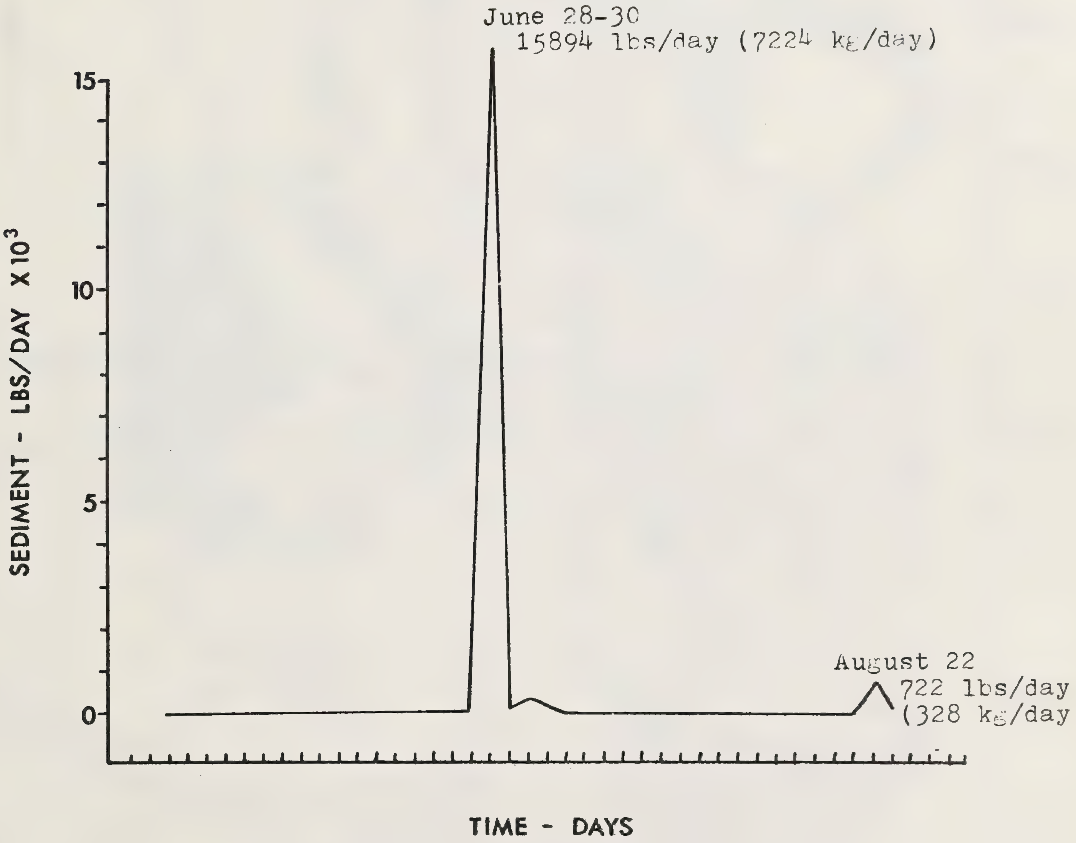


Figure 48

Plane view map of MC0607, August 1976, showing bare soil areas.

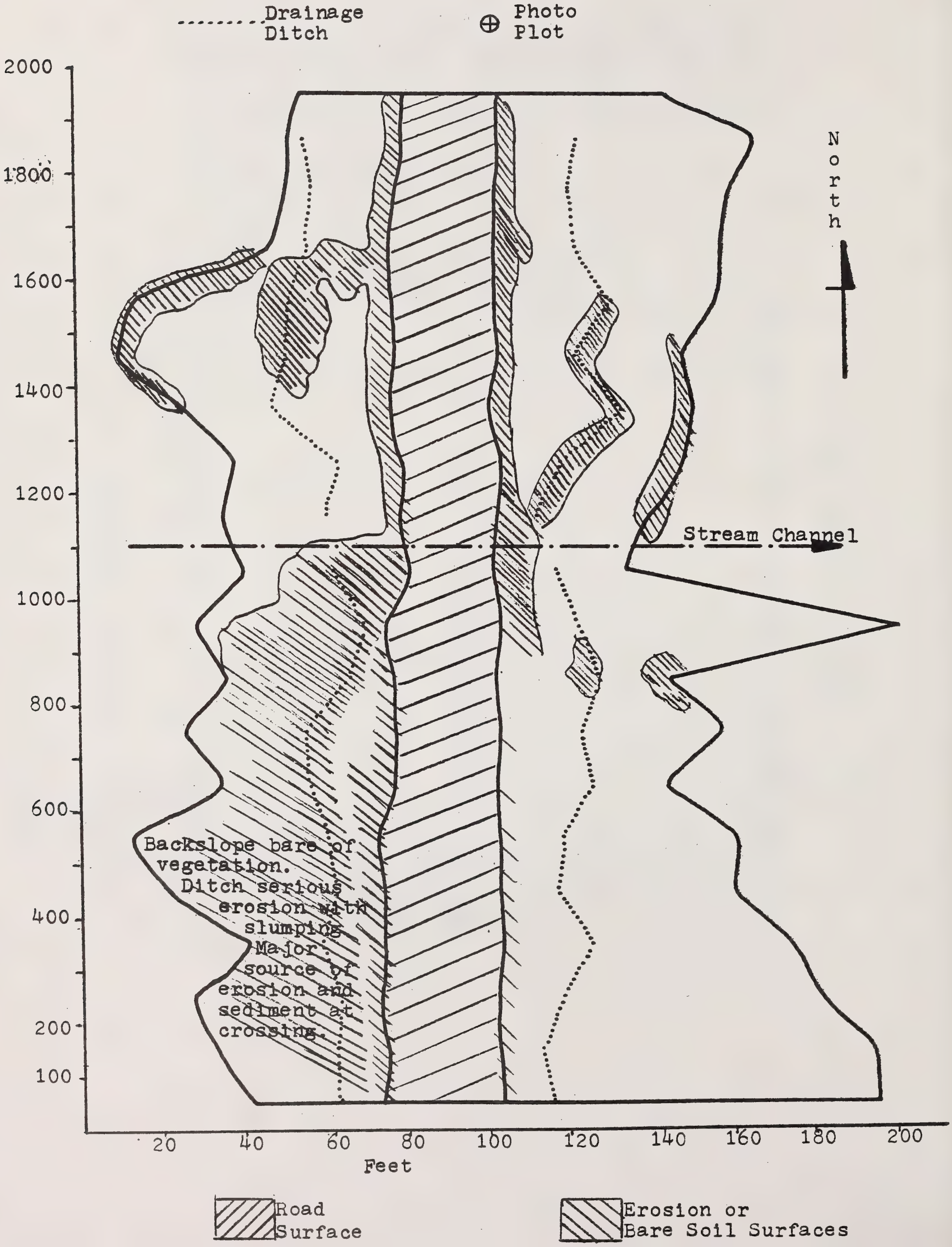
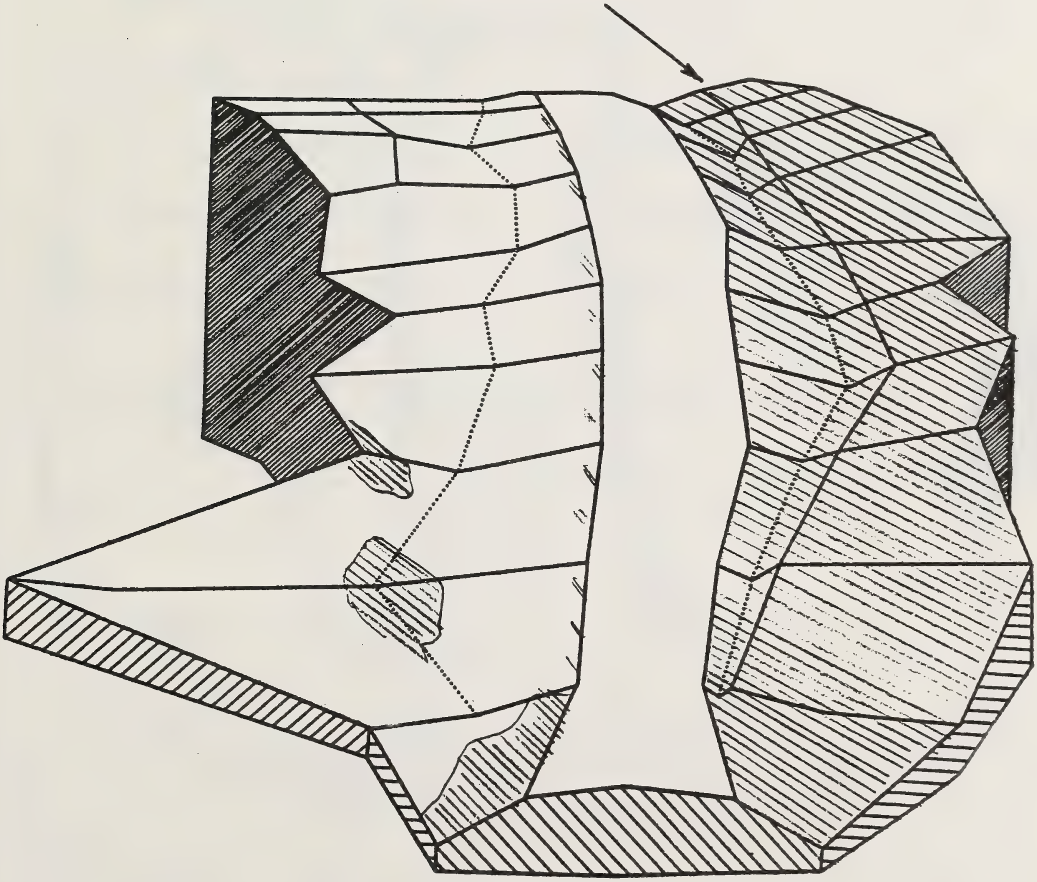

Drainage Ditch
Photo Plot
2000
1800
1600
1400
1200
1000
800
600
400
200
100
North
Stream Channel
Backslope bare of vegetation.
Ditch serious erosion with slumping. Major source of erosion and sediment at crossing.
20
40
60
80
100
120
140
160
180
200
Feet
Road Surface
Erosion or Bare Soil Surfaces

Figure 49

Road Crossing MC0607 - South Half

Bare soil areas as of 1976 shown by cross-hatching

Backslope major source of erosion and sediment. Deep cut intercepted groundwater discharge area. Ditch soil always wet and subject to slumping. Steep slope of ditch and high runoff during precipitation results in high sediment transport.

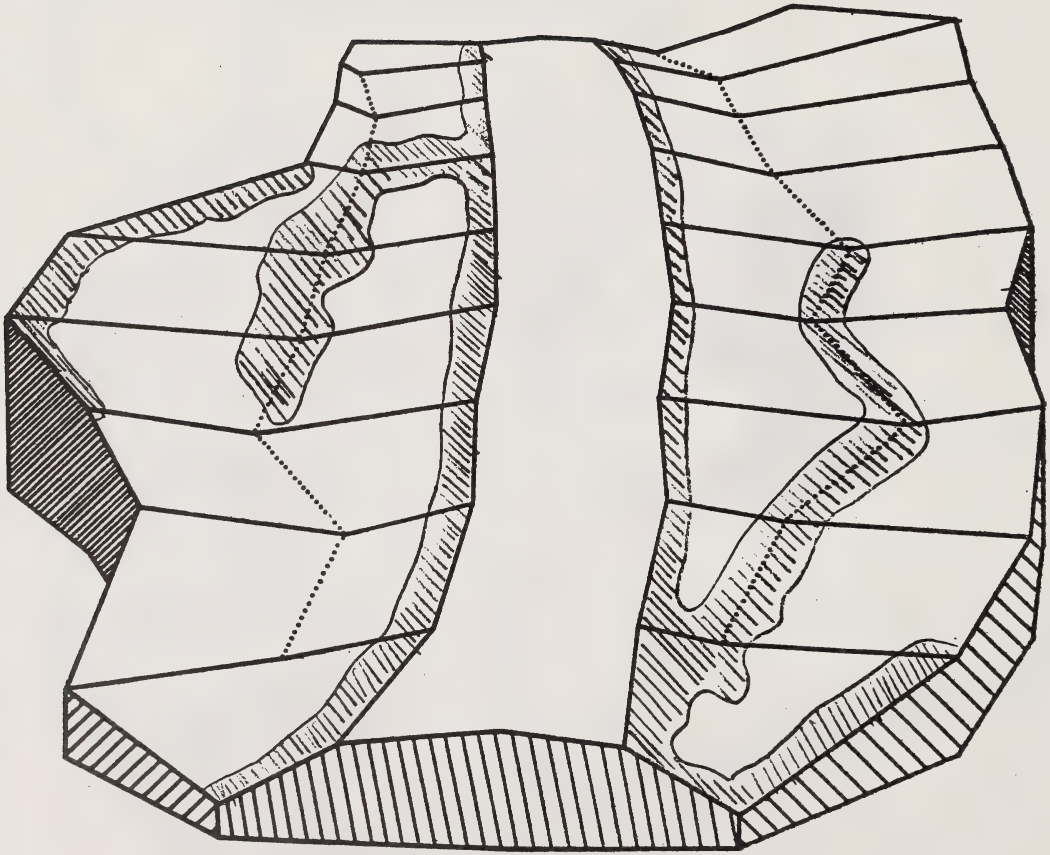


Excessive deposition of sediments at culvert inlet.

Figure 50

Road Crossing MC0607 - North Half

Bare soil areas as of 1976 shown by cross-hatching



Road Stream Crossing - ER5 - Hanlan Creek
Location: Section 15, Township 49, Range 18

Area Treated: 0.75 ha

17% road surface
23% road shoulder
50% backslope

Road Description:

second class road	
bridge crossing	
depth of fill over culvert	n/a
road distance	396.0 m
road gradient approaches	8%, 6%

Stream Channel and Streamflow:

mean summer flow	0.905 m^3/sec
maximum flow	
1975	3.65 m^3/sec
stream width-depth	6.7 - 0.30 m
stream order	3 rd

Sediment Flows:

1975	
Sediment Concentration	
mean seasonal	
upstream	12.0 mg/1
downstream	13.0 mg/1
storms	
June 28-30, 1975	
upstream	35.0 mg/1
downstream	40.0 mg/1
Sediment Production	
seasonal	53.9 kg/ha/day
storm	
June 28-30, 1975	450.7 kg/ha/day

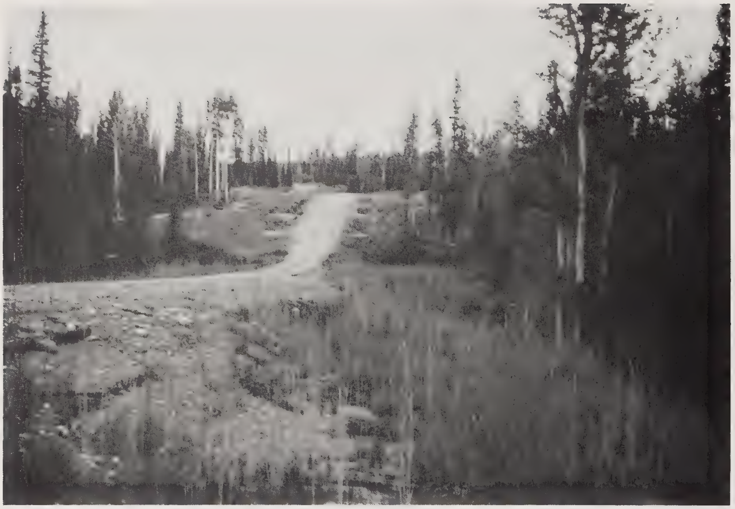


Figure 51. ER5 - North Half in 1976

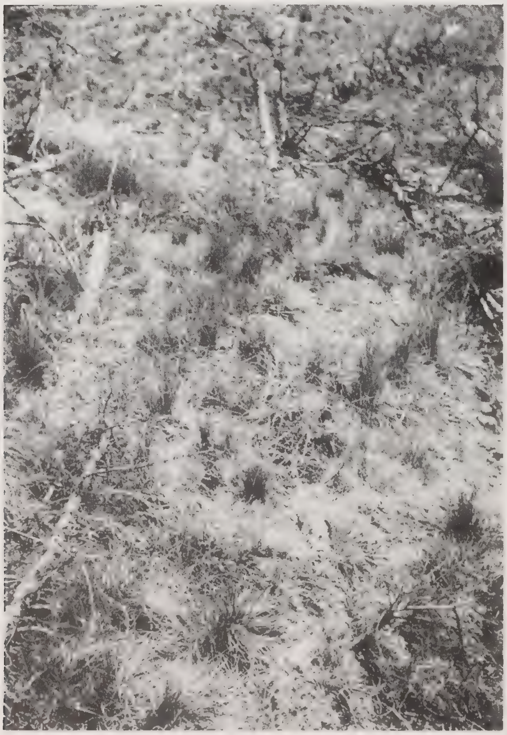


Figure 52. ER5 NE Backslope in 1976. Note Rate and Extent of Grass Development Around Logging Debris.

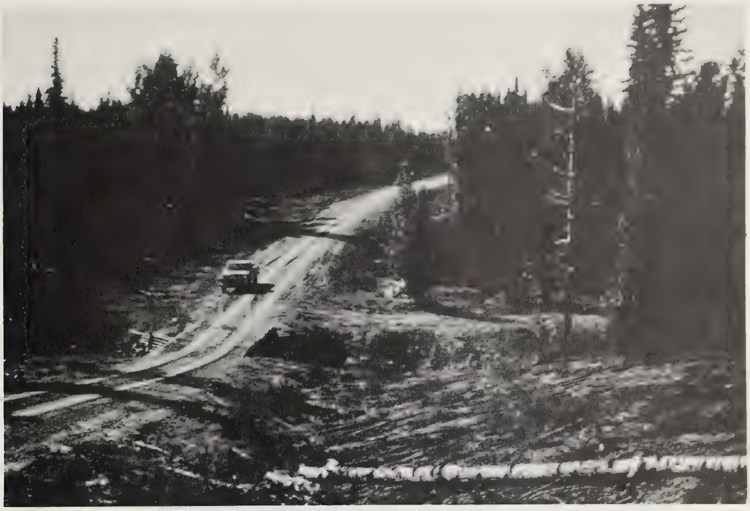


Figure 53. ER5 - South Half in 1975 Following Application of Grass and Brush Mulch.

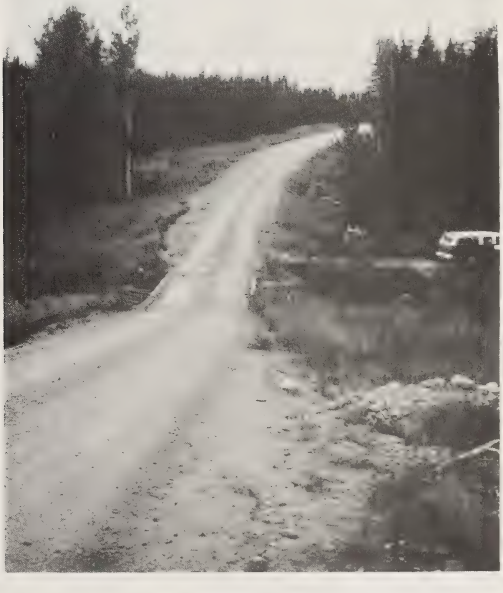


Figure 54. ER5 - South Half in June - 1976.

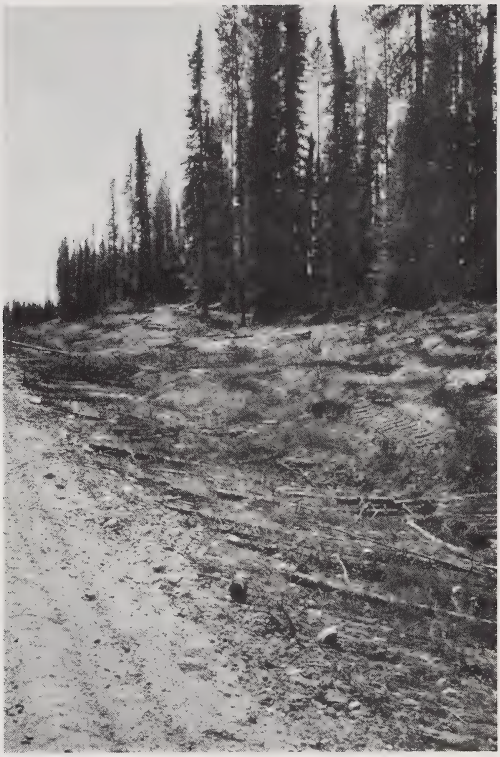


Figure 55. ER5 - South Half, West Road Side Drainage Ditch - 1976.

Figure 56

Road Stream Crossing ER-5

Sediment Flows: May 15 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

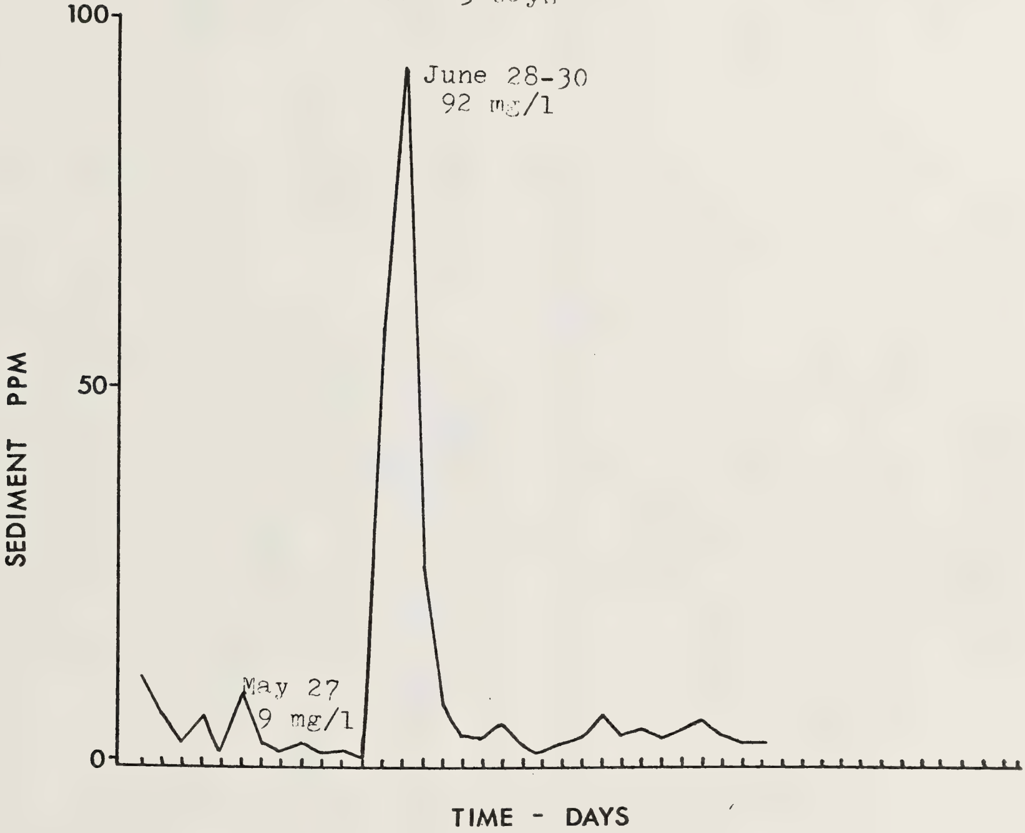


Figure 57

Road Stream Crossing ER-5

Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day

Abscissa: 1 unit = 3 days

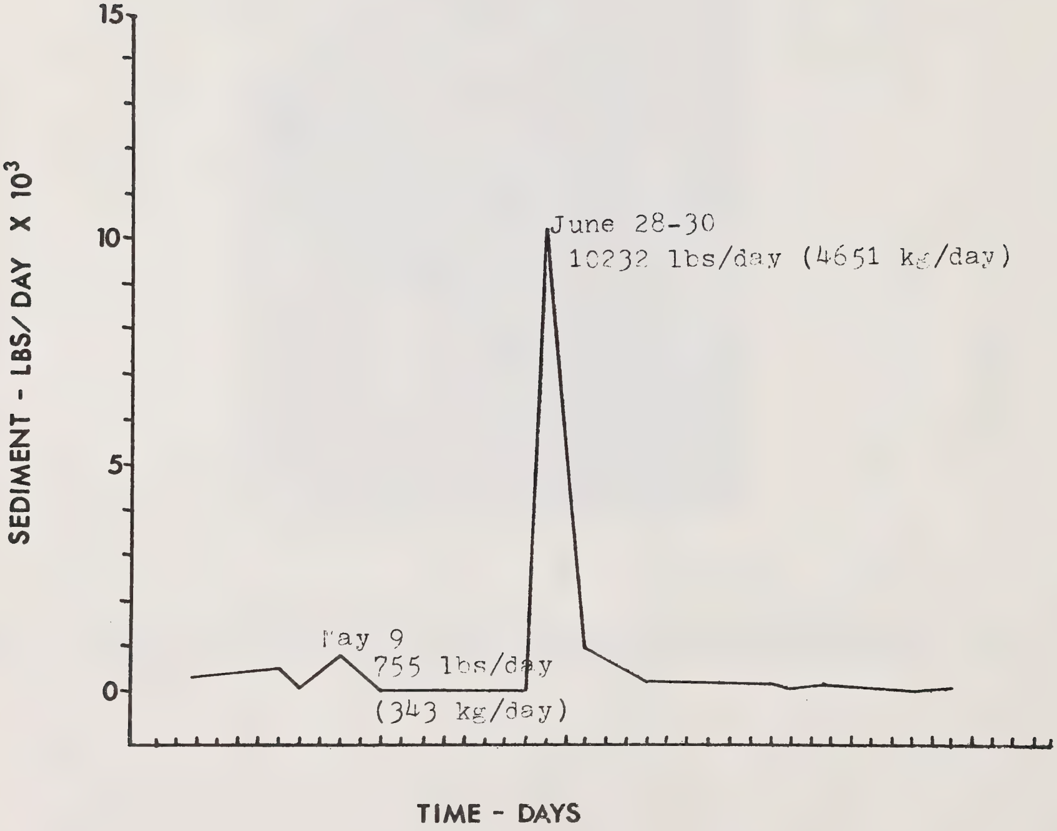


Figure 58
Plane view map of ER-5, August 1976, showing bare soil areas.

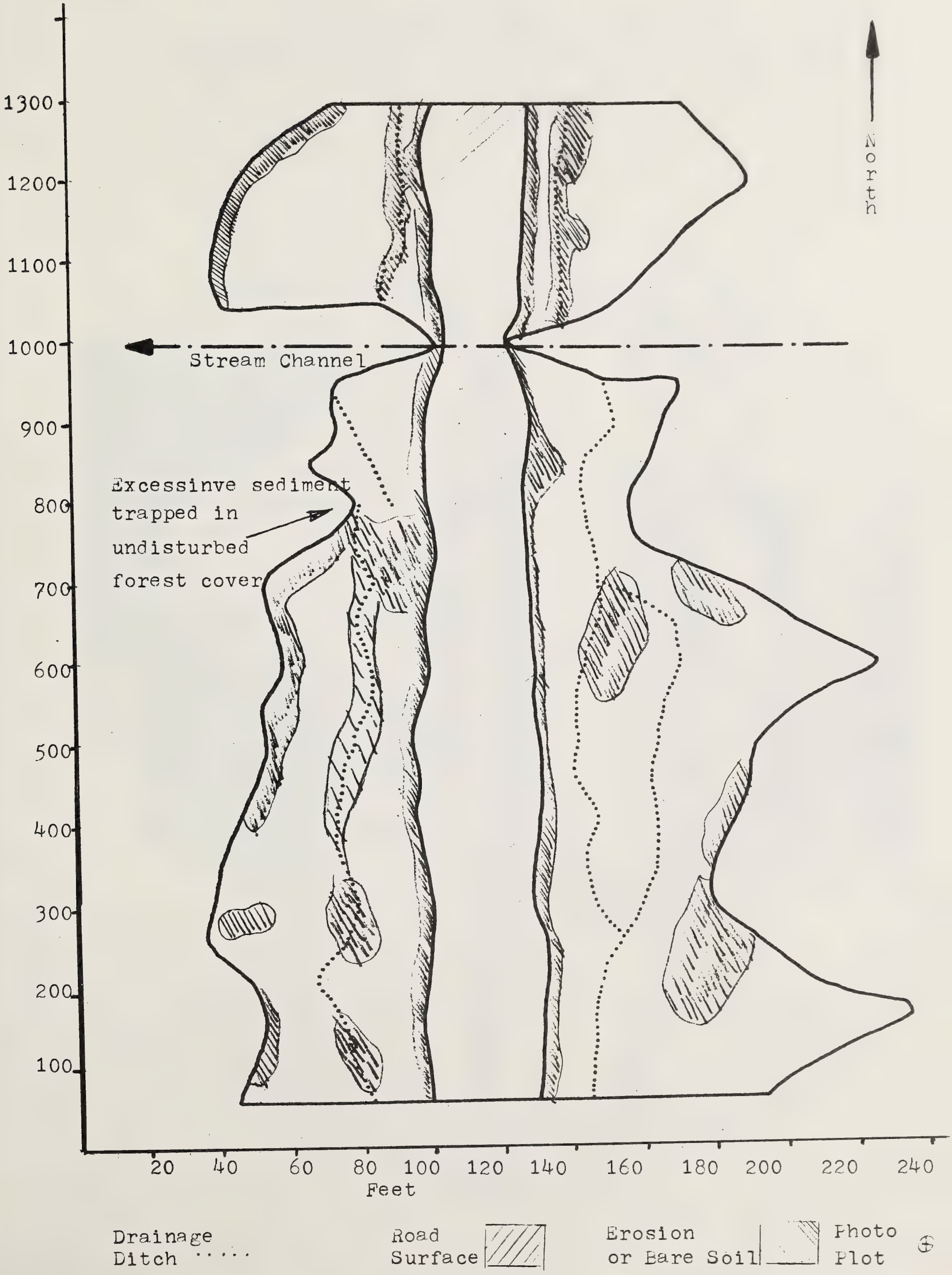


Figure 59

Road Crossing ER-5 - North Half

Bare soil areas as of 1976 shown by cross-hatching

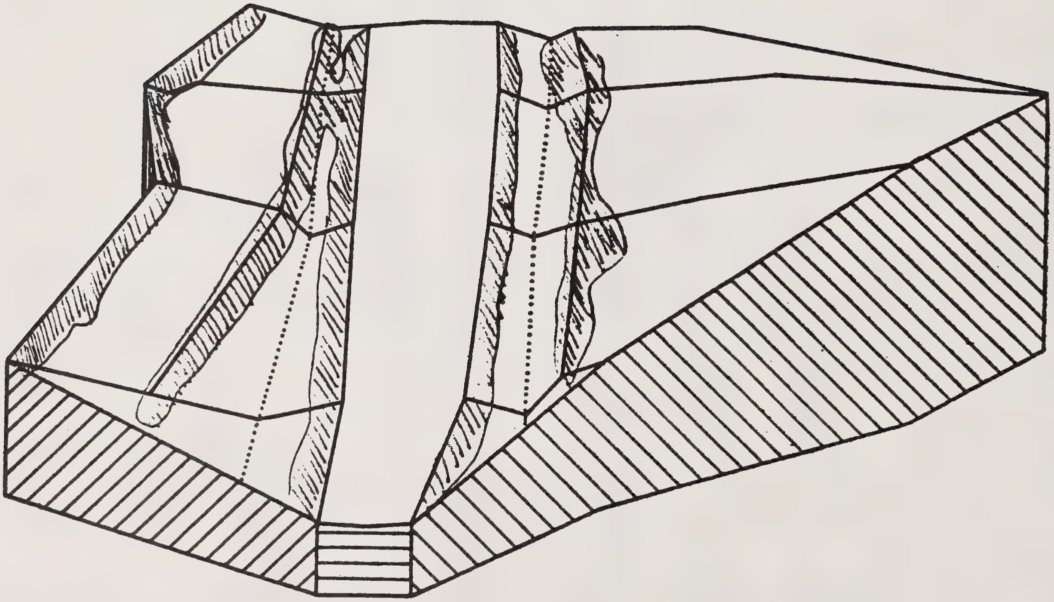
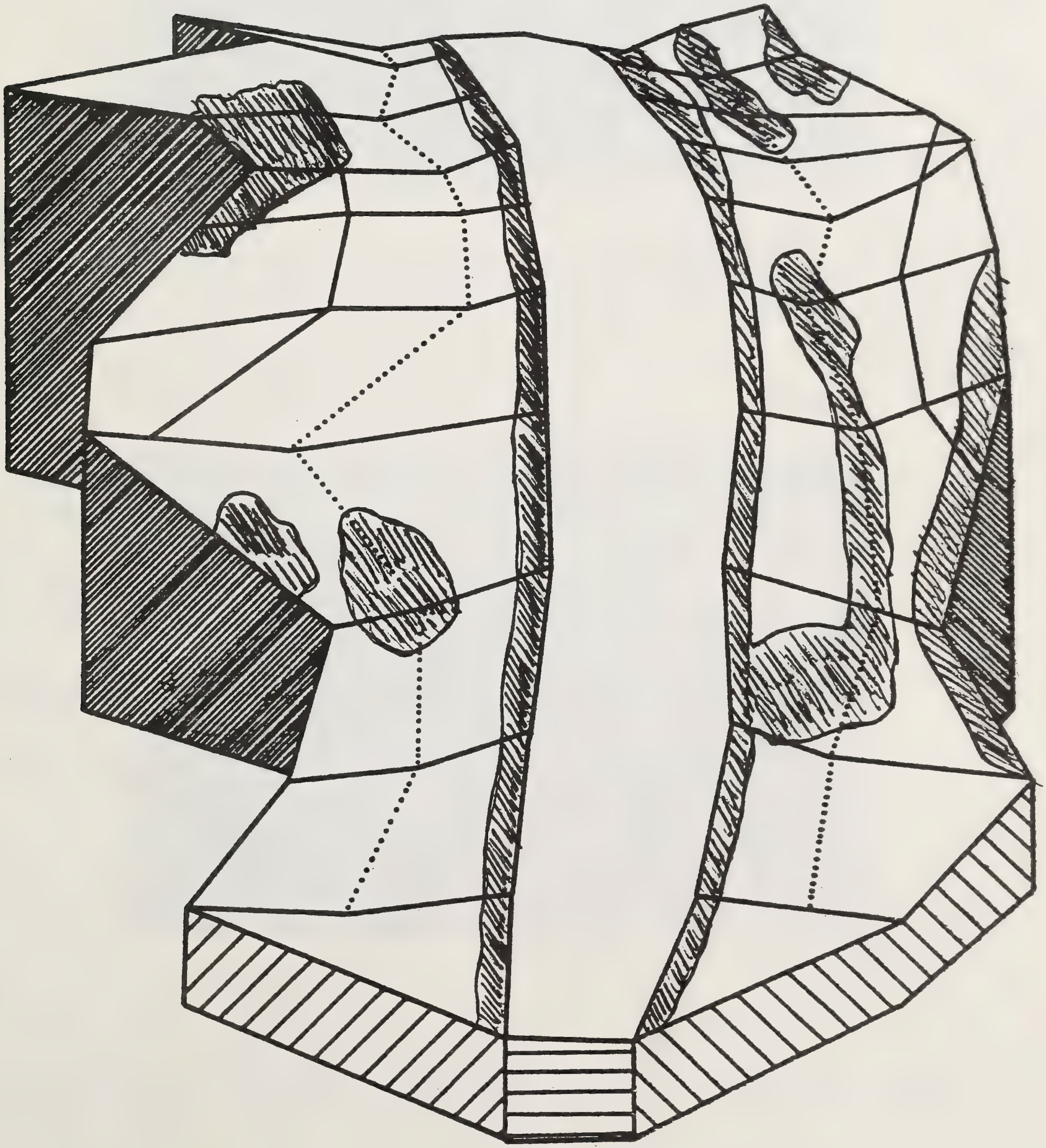


Figure 60

Road Crossing ER-5 - South Half

Bare soil areas as of 1976 shown by cross- hatching



Road Stream Crossing - MC0618 - White Creek
Location: Section 19, Township 50, Range 22

Area Treated: 0.63 ha.

25% road surface
23% road shoulder
52% backslope

Road Descritpion:

second class road	
culver crossing	
depth of fill over culvert	2.13 m
road distance	213.0 m
road gradient approaches	5%, 4%

Stream Channel and Streamflow :

mean summer flow	0.0410 m^3/sec
maximum flow	0.2209 m^3/sec
stream width-depth	1.52 - 0.32 m
stream order	2 nd

Sediment Flows:

1975	
Sediment Concentration	
mean seasonal	
upstream	6.0 mg/1
downstream	6.0 mg/1
storm	
June 28-30, 1975	
upstream	4.0 mg/1
downstream	9.0 mg/1
Sediment Production	
seasonal	83.90 kg/ha/day
storm	
June 28-30, 1975	355.5 kg/ha/day

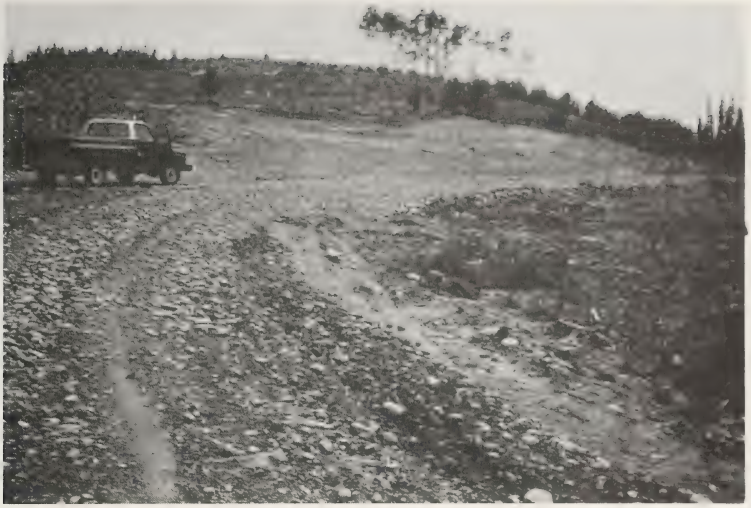


Figure 61. MC0618 - NE Backslope (Quadrant) Following Treatment of Grass Sowing June 1975.

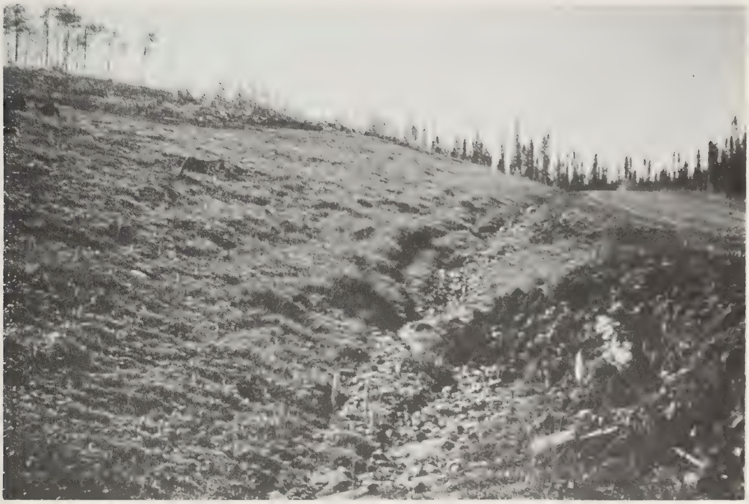


Figure 62. MC0618 - NE Backslope (Quadrant) in Late August 1975.

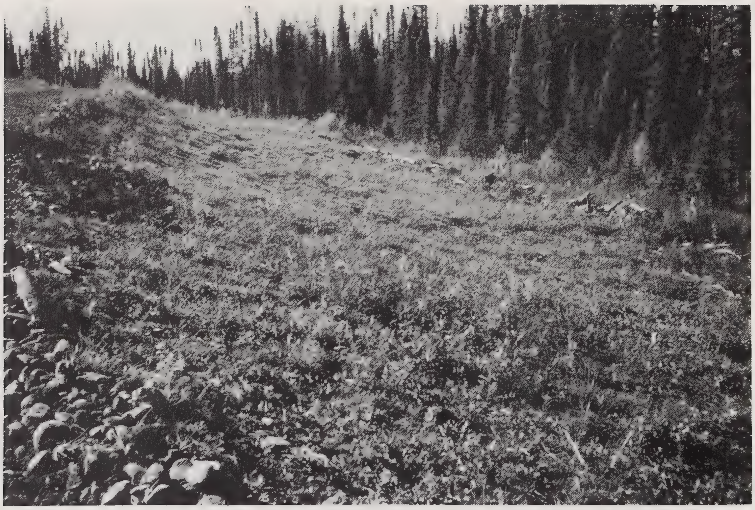


Figure 63. MC0618 - SE Backslope (Quadrant) in Late August 1975. Heavy Cover of Clover.

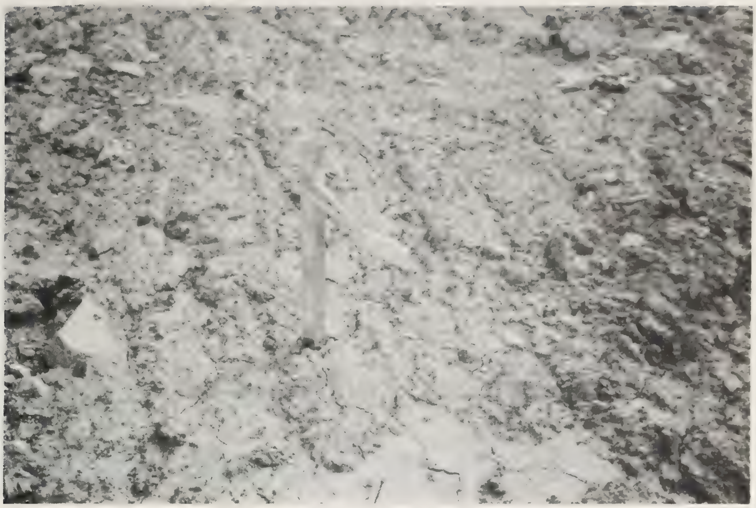


Figure 64. MC0618 - Photo Plot Following Treatment of Grass Sowing. Newly Established Clover Barely Visible - 1975.

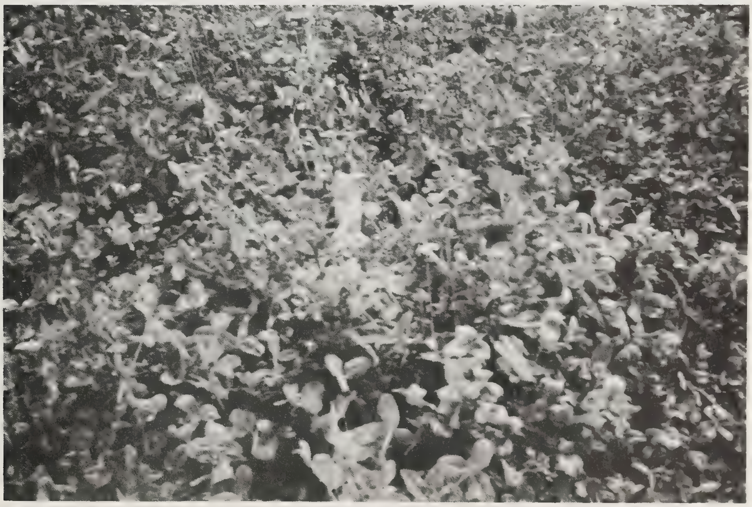


Figure 65. MC0618 - Photo Plot in 1976 With Heavy Clover Cover.

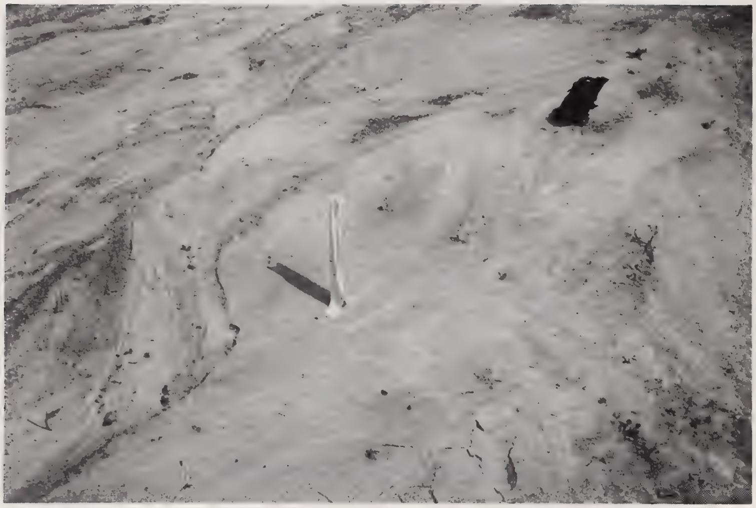


Figure 66. MC0618 - Photo Plot Following Treatment of Grass Sowing.

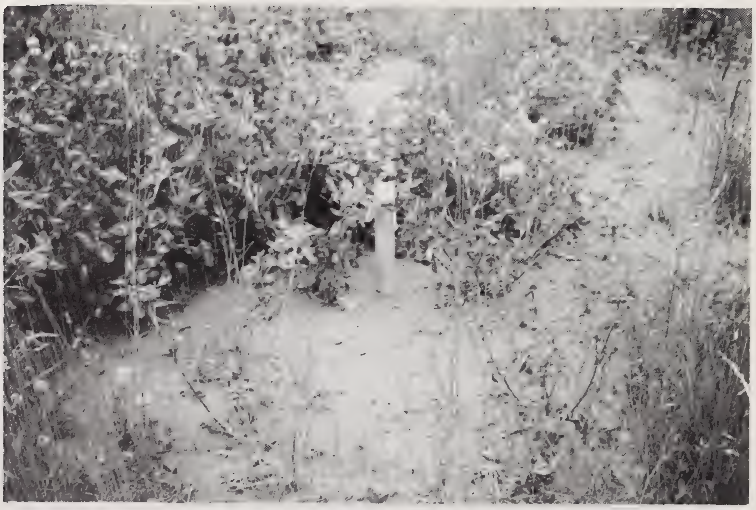


Figure 67. MC0618 - Photo Plot in 1976.

Figure 68

Road Stream Crossing KC0618

Sediment Flows 1975: May 15 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

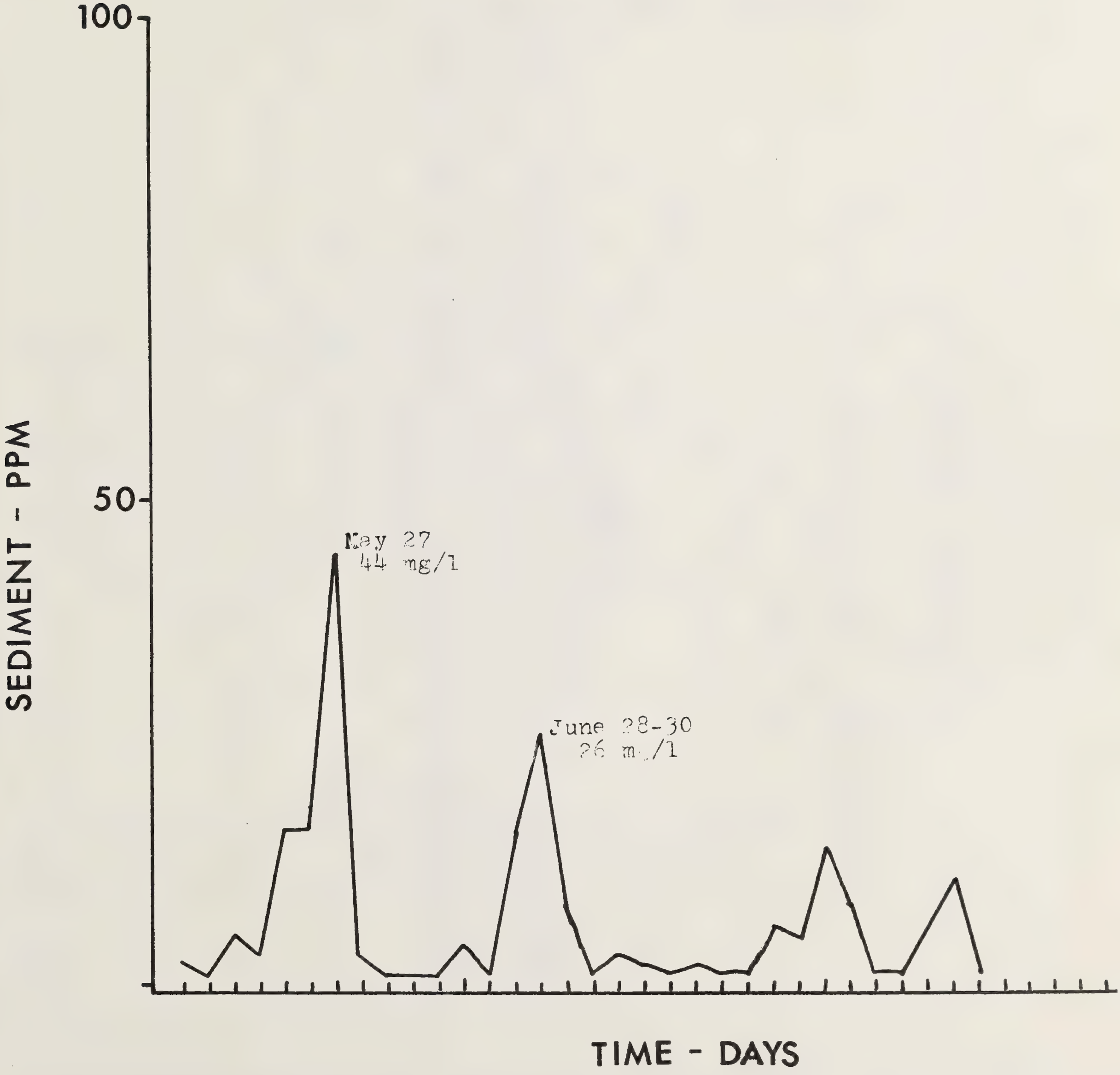


Figure 69

Road Stream Crossing MC0618

Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

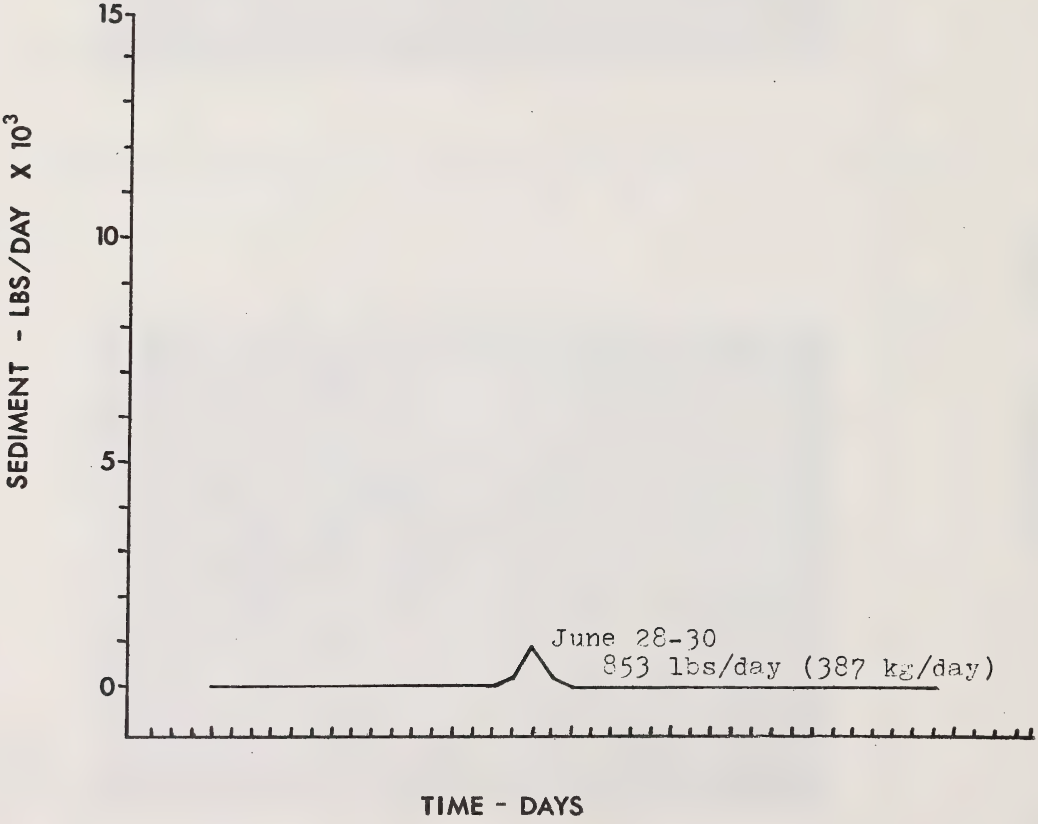


Figure 70

Plane view map of MC0618, August 1976, showing bare soil areas.

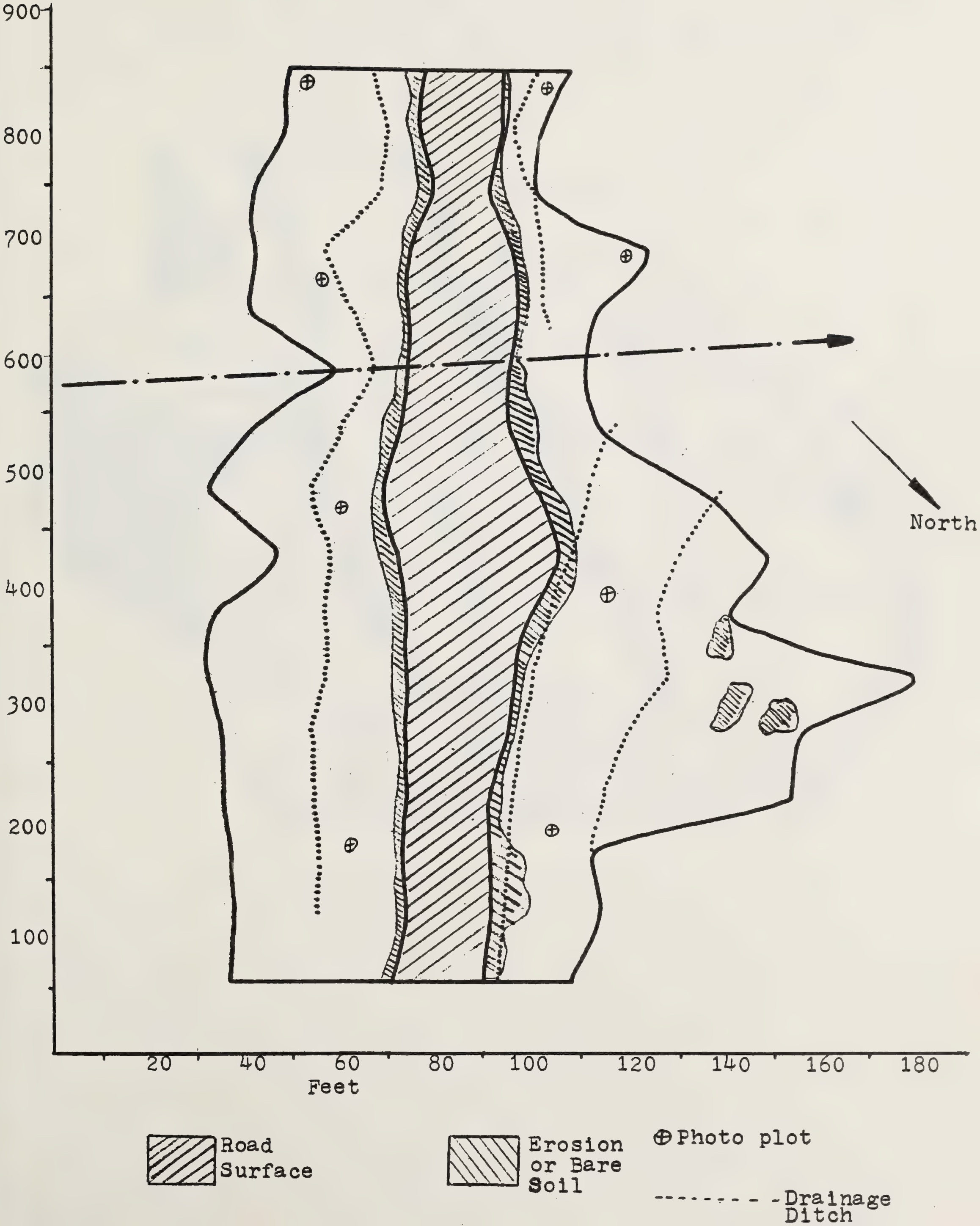


Figure 71

Road Crossing MC0618 - West Half

Bare soil areas as of 1976 shown by cross-hatching

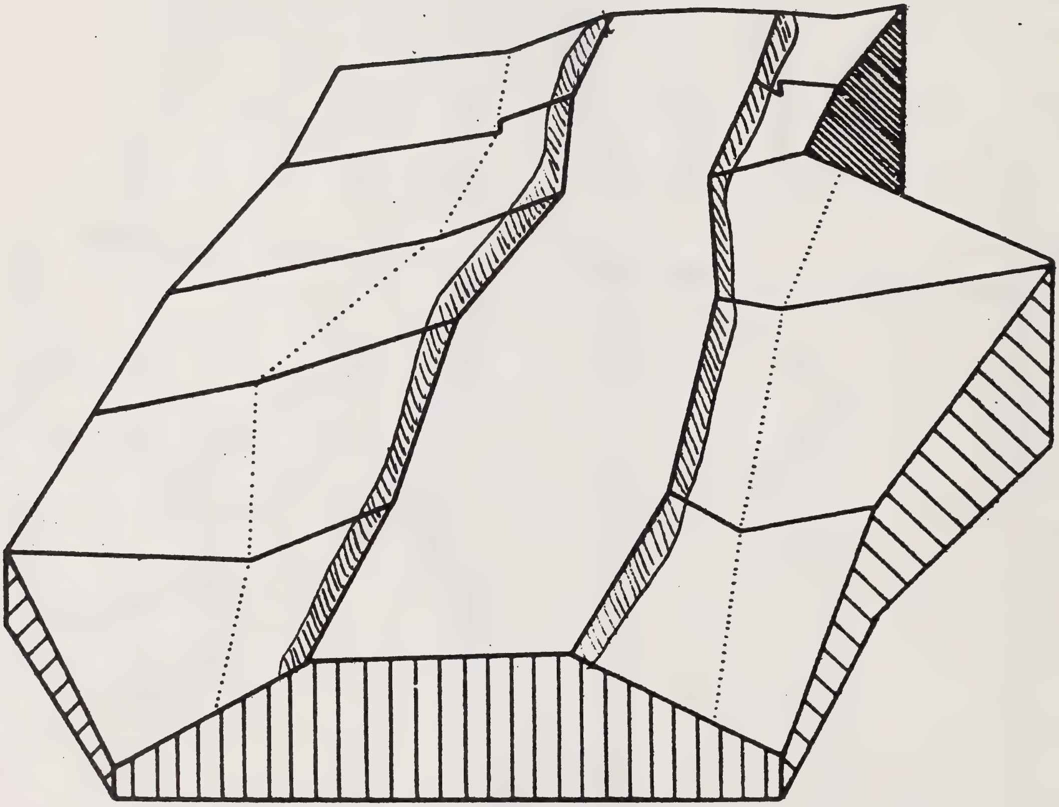
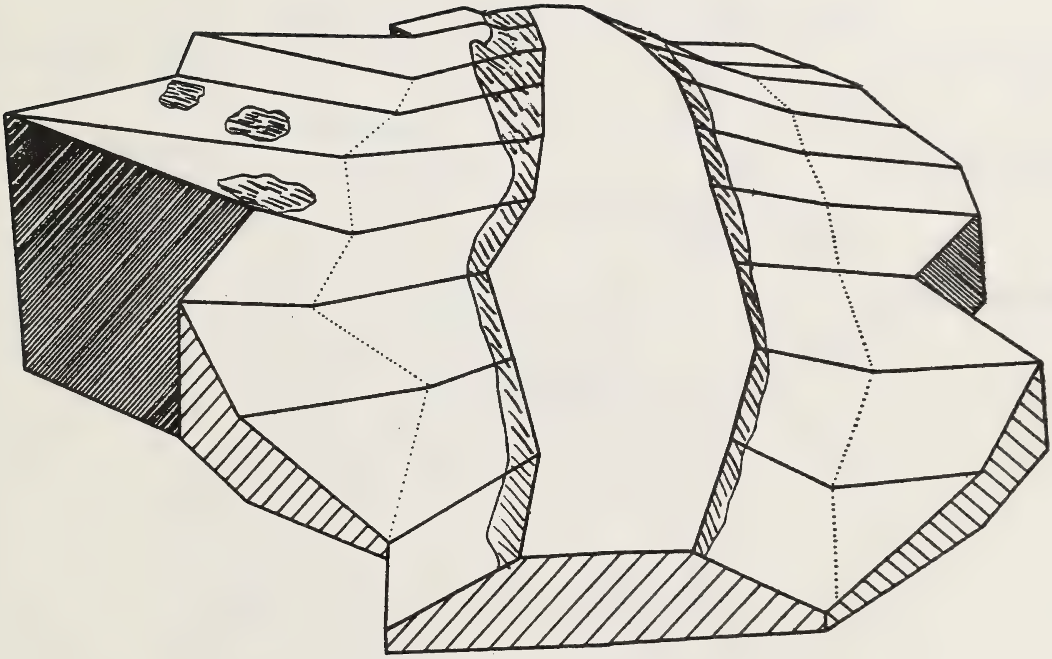


Figure 72

Road Crossing MC0618 - West Half

Bare soil areas as of 1976 shown by cross-hatching



Road Crossing - ER-1 - Erith River
Location: Section 9, Township 49, Range 19, W5M

Area Treated: 0.90 ha

Road Description:

second class	
culvert crossing	
depth of fill over culvert	not available
road distance	n.a.
road gradient approaches	n.a.

Stream Description:

mean summer flow	
1974	0.049 m^3/sec
1975	0.039 m^3/sec
maximum flow	
1974	0.142 m^3/sec
1975	0.099 m^3/sec
stream width-depth	2.1-0.13 m
stream order	1st

Sediment Flows:

1974	
Sediment Concentration	
mean seasonal	
upstream	12.0
downstream	66.0
storms	
June 21-28	
upstream	12.0
downstream	57.0
July 9-13	
upstream	17.0
downstream	61.0
Sediment Production	
seasonal	222.0 kg/ha/day
storms	
June 21-28	136.0 kg/ha/day
July 9-13	250.0 kg/ha/day

Road Crossing - ER-1 - continued

Sediment Flows:

1975	
Sediment Concentration	
mean seasonal	
upstream	30.0
downstream	42.0
storms	
June 28-30	
upstream	84.0
downstream	121.0
Sediment Production	
seasonal	55.0 kg/ha/day
storms	
June 28-30	104.5 kg/ha/day

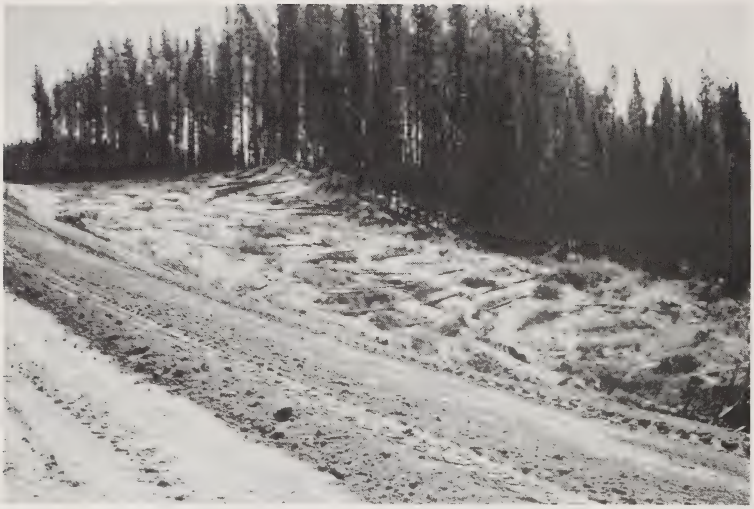


Figure 73. ER2 - SE Quadrant Following Application of Brush Mulch - 1974.

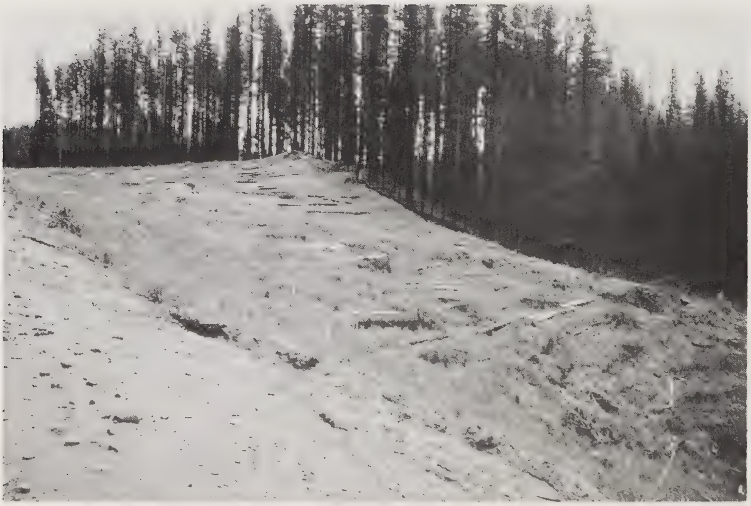


Figure 74. ER1 - SE Quadrant in June 1976.

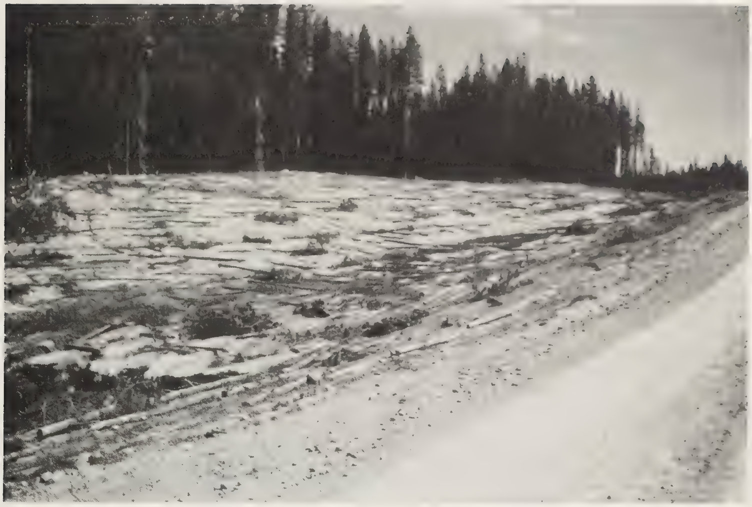


Figure 75. ER1 - NE Quadrant Following Brush Mulch Application - 1974.

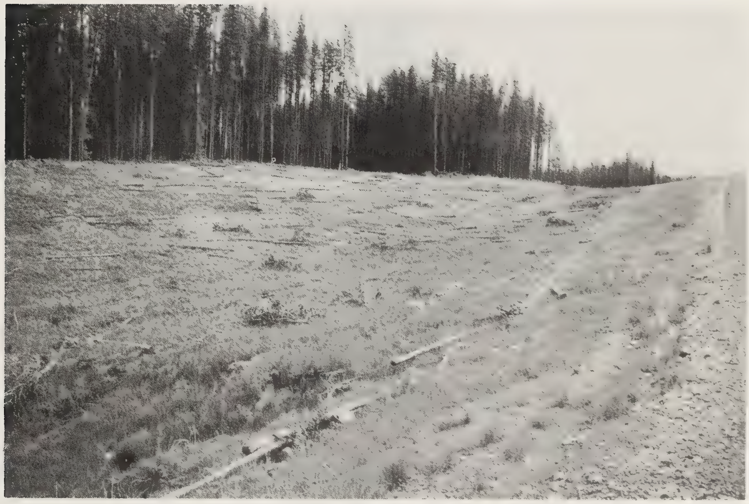


Figure 76. ER1 - NE Quadrant in 1976. Note Upper Backslope in Middle Photograph is Still Bare.

Figure 77
Road Stream Crossing ER-1

Sediment Flows 1974: May - August 23

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa 1 unit = 3 days

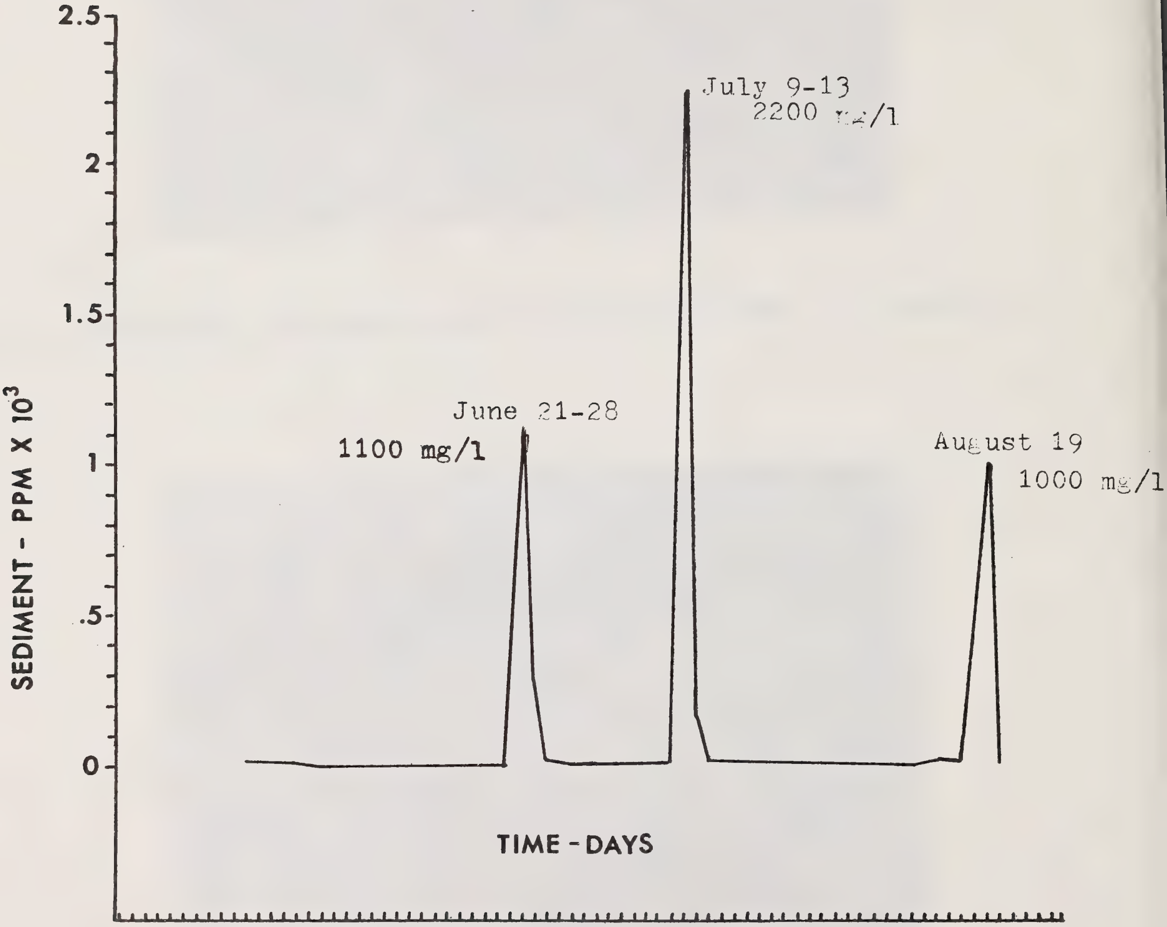


Figure 78

Road Stream Crossing ER-1
Sediment Flows 1975 May 15 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

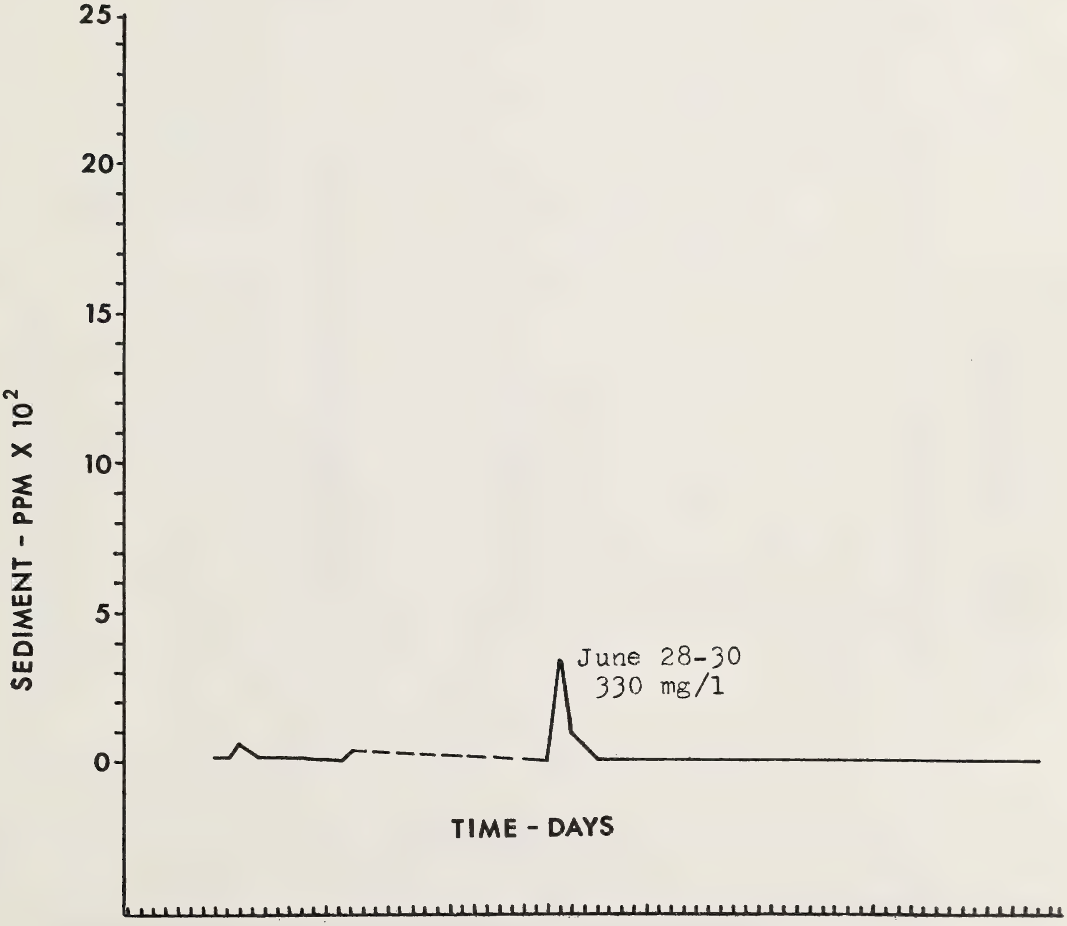


Figure 79

Road Stream Crossing ER-1

Sediment Production 1974: May 5 - August 23

Ordinate: lbs/day

Abscissa: 1 unit = 3 days

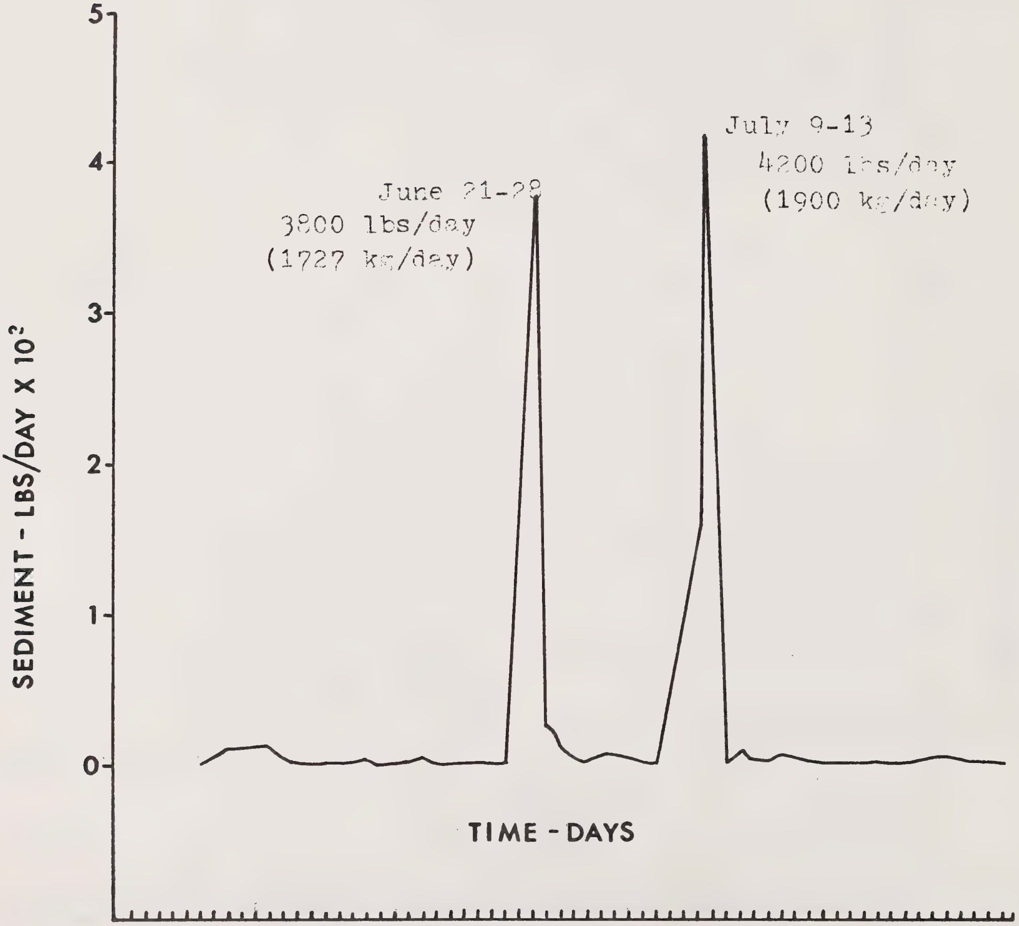


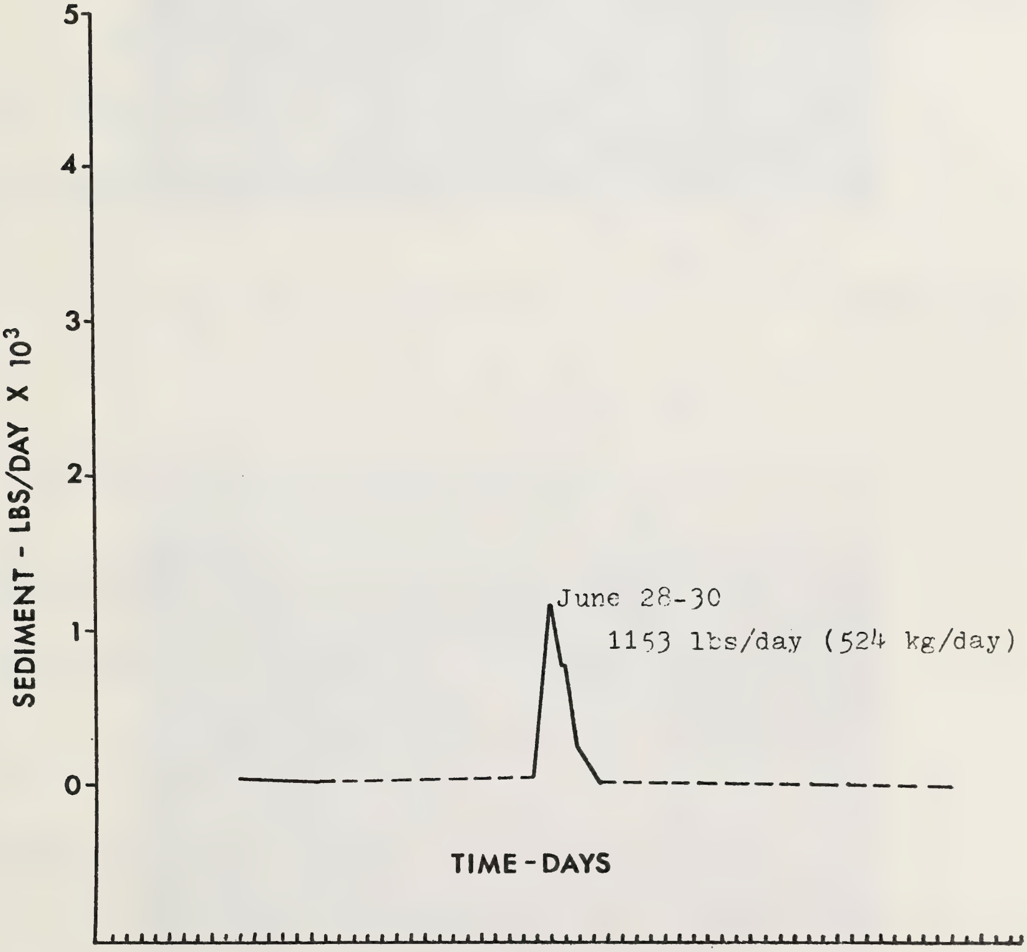
Figure 80

Road Stream Crossing ER-1

Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day

Abscissa: 1 unit = 3 days



Road Stream Crossing - ER2 - Erith River
Location: Section 3, Township 49, Range 19

Area Treated: 1.02 ha

Road Description:

second class road	
culvert crossing	
depth of fill over culvert	n/a
road distance	n/a
road gradient approaches	n/a

Stream Channel and Streamflow :

mean summer flow	
1974	0.074 m^3/sec
1975	0.078 m^3/sec
maximum flow	
1974	0.169 m^3/sec
1975	0.178 m^3/sec
stream width-depth	2.13 - 0.12 m
stream order	1 st

Sediment Flows:

1974	
Sediment Concentration	
mean seasonal	
upstream	30.0 mg/1
downstream	156.0 mg/1
storms	
June 21-28, 1974	
upstream	29.0 mg/1
downstream	285.0 mg/1
July 9-13, 1974	
upstream	145.0 mg/1
downstream	551.0 mg/1
Sediment Production	
seasonal	424 kg/ha/day
storm	
June 21-28, 1974	798.5 kg/ha/day
July 9-13, 1974	1511.0 kg/ha/day
1975	
Sediment Concentration	
mean seasonal	
upstream	45.0 mg/1
downstream	59.0 mg/1
storms	
June 28-30, 1975	
upstream	119.0 mg/1
downstream	140.0 mg/1
Sediment Production	
seasonal	44.6 kg/ha/day
storm	
June 28-30, 1975	95.0 kg/ha/day

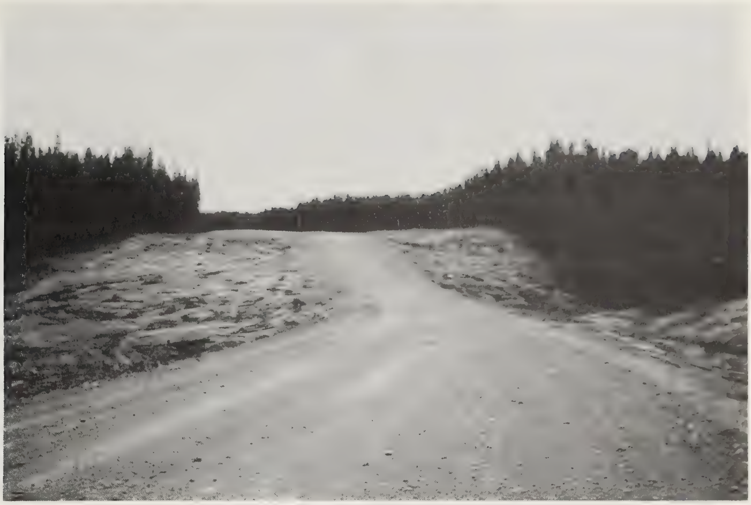


Figure 81. ER2 - East Half Following Brush Mulch Application - 1974.

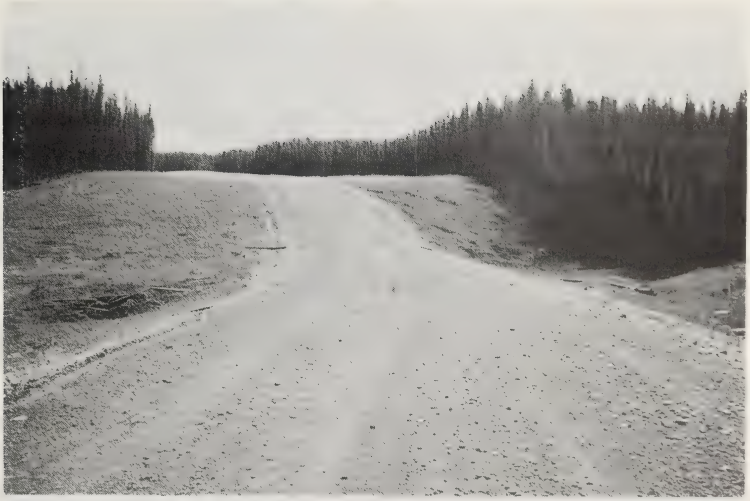


Figure 82. ER2 - East Half in 1976. Note, Logging Debris Not Highly Visible.

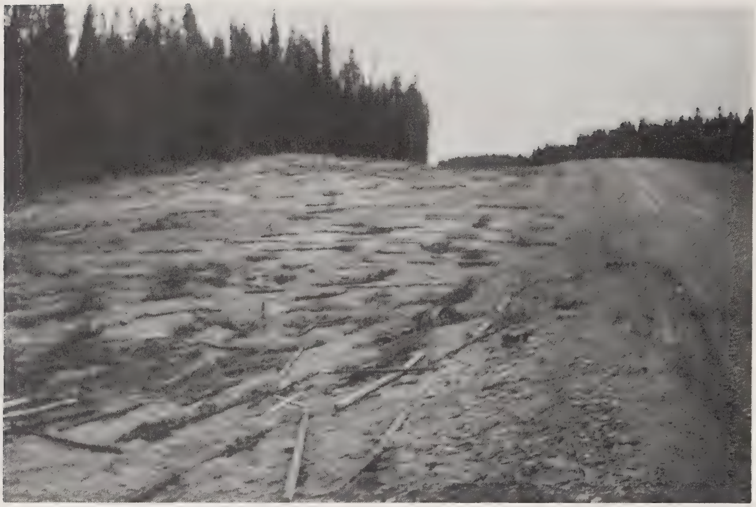


Figure 83. ER2 - NE Quadrant - 1974 - Following Brush Mulch Application.

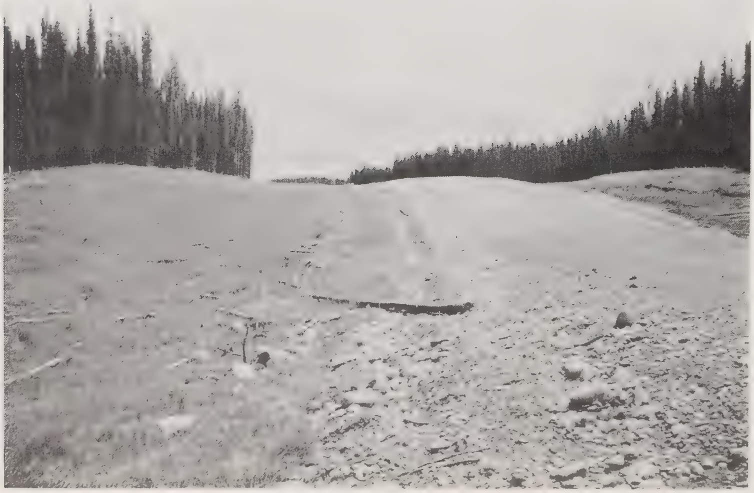


Figure 84. ER2 - NE Quadrant in 1976.

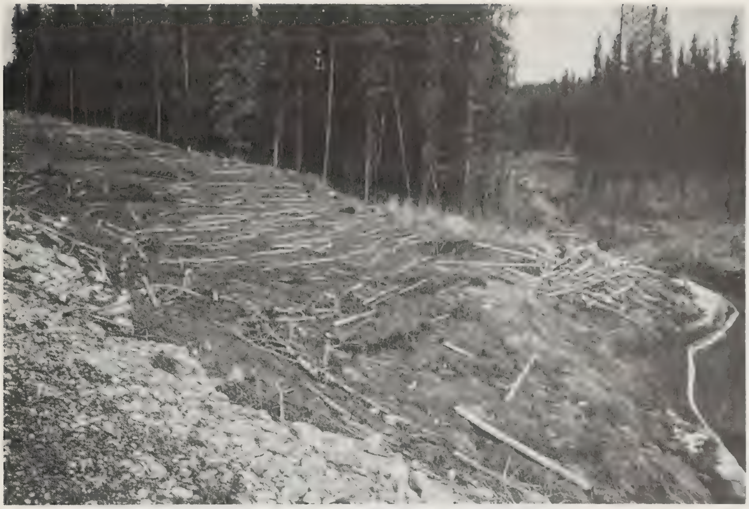


Figure 85. ER2 - NW Quadrant in Spring of 1975. Debris Highly Visible.

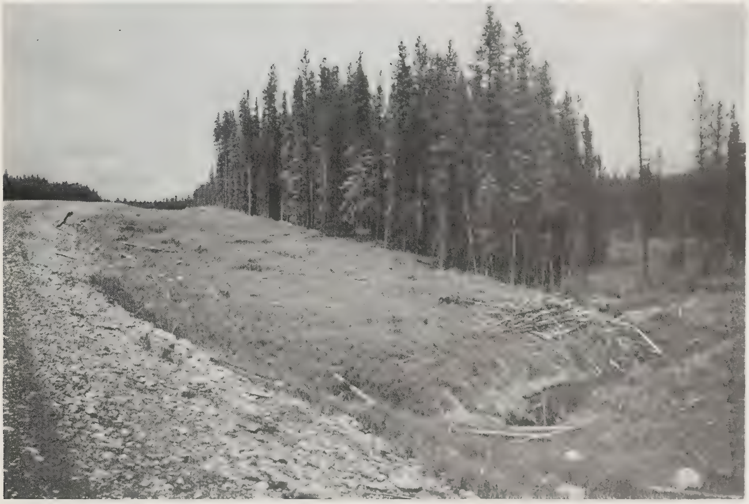


Figure 86. ER2 - NW Quadrant in August 1975.

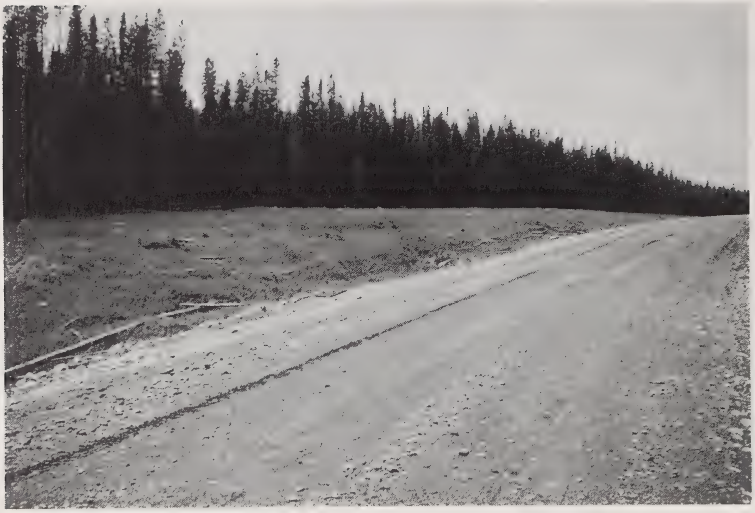


Figure 87. ER2 - SW Quadrant 2 - 3 Weeks After Brush Mulch Application - 1974.

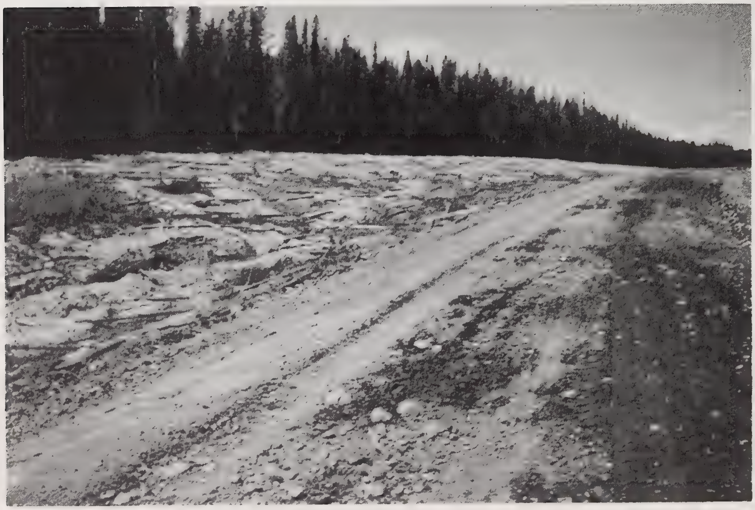


Figure 88. ER2 - SW Quadrant in 1975.

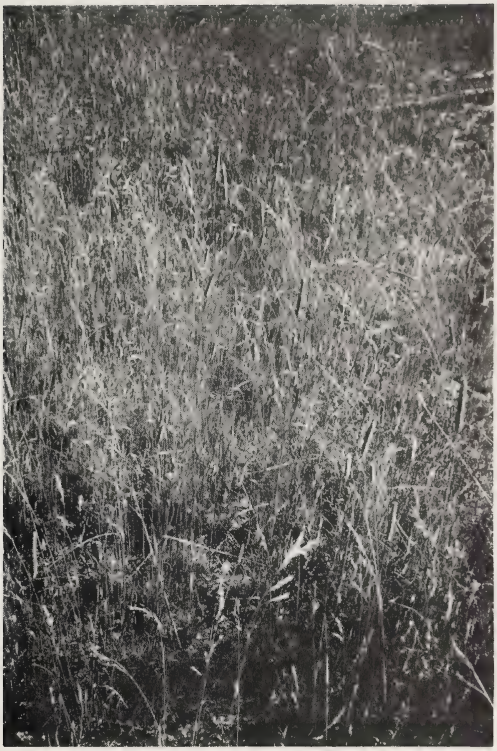


Figure 89. ER2 - Grass Cover on NE Quadrant in August 1976.

Figure 90

Road Stream Crossing ER-2

Sediment Flows 1974: May 5 - August 23

Taken at downstream sampling station

Ordinate: ppm or mg/l

Abscissa: 1 unit = 3 days

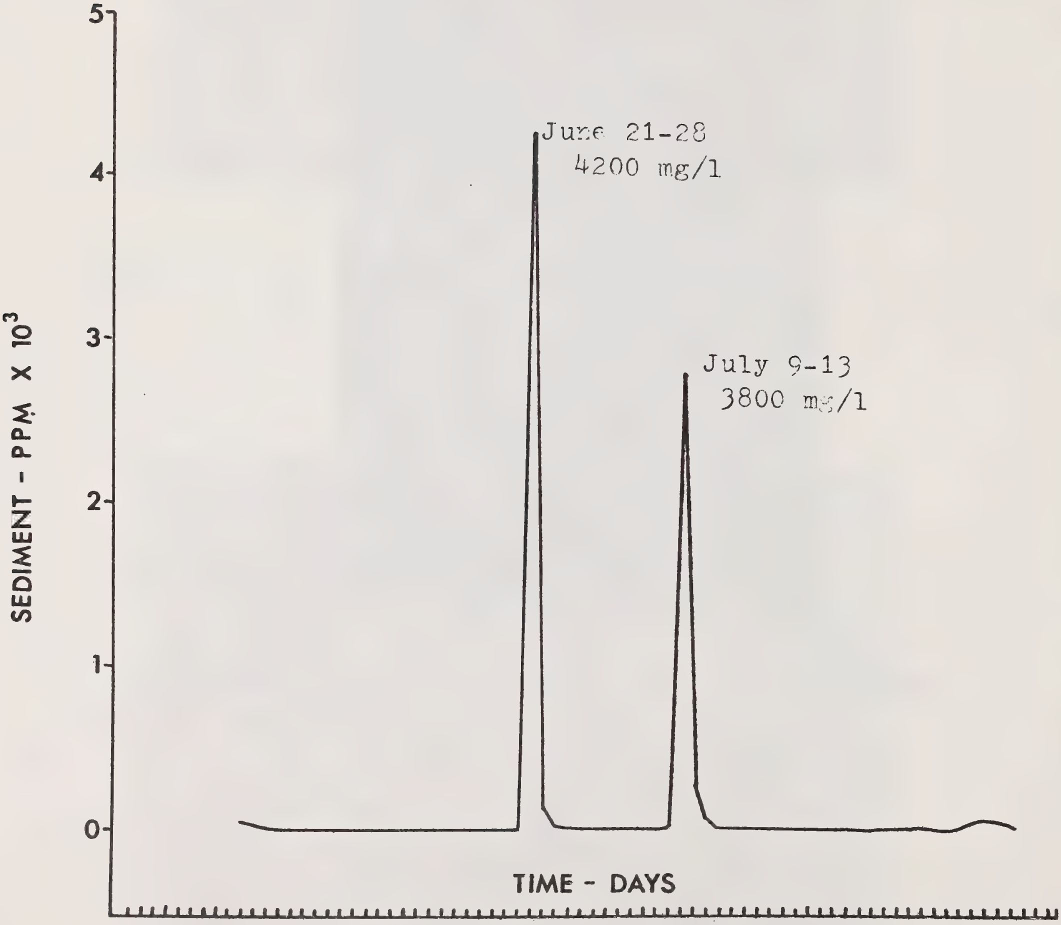


Figure 91

Road Stream Crossing ER-2
Sediment Flows 1975: May 15 - August 26

Taken at downstream sampling station
Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

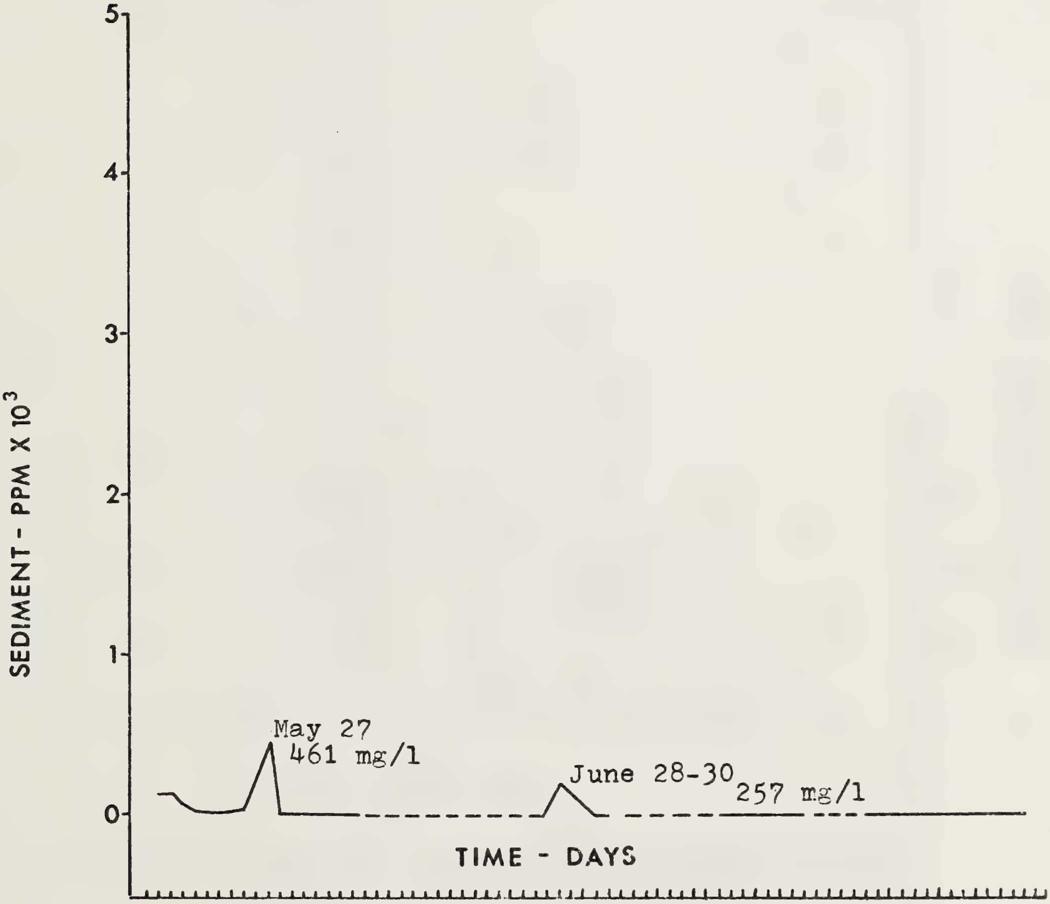


Figure 92

Road Stream Crossing ER-2

Sediment Production 1974: May 5 - August 23

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

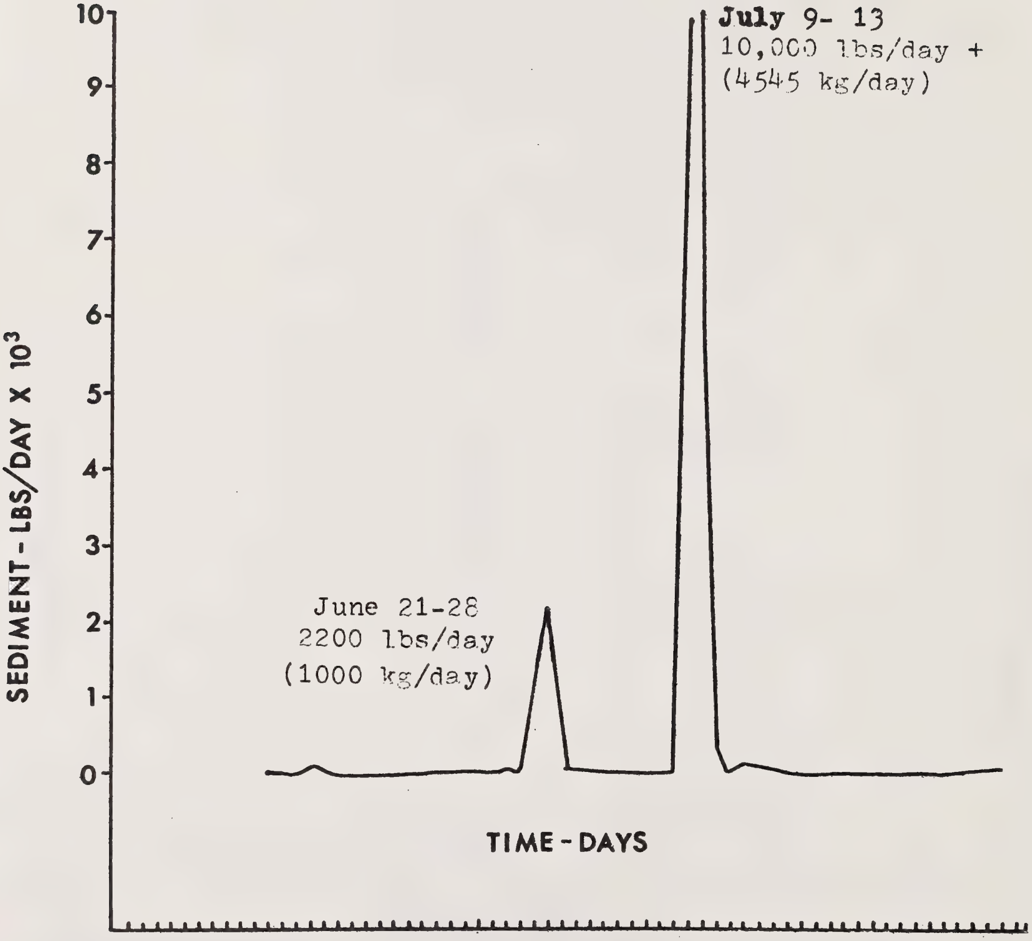
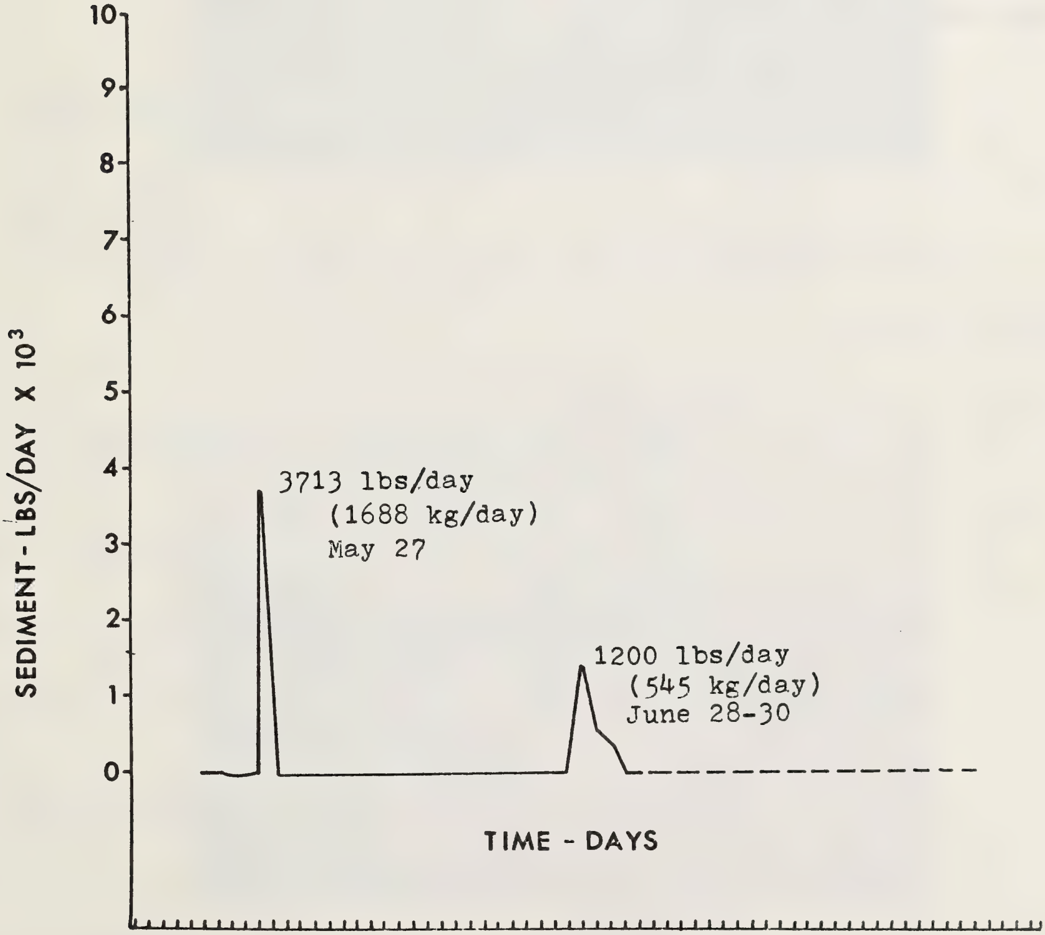


Figure 93

Road Stream Crossing ER-2

Sediment Production 1975: May 15 - August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days



Road Stream Crossing - ER3 - Erith River
Location: Section 3, Township 49, Range 19

Area Treated: 1.52 ha

Road Description:

second class road	
culvert crossing	
depth of fill over culvert	n/a
road distance	n/a
road gradient approaches	n/a

Stream Channel and Streamflow:

mean summer flow	
1974	0.0147 m^3/sec
1975	0.041 m^3/sec
maximum flow	
1974	0.186 m^3/sec
1975	0.085 m^3/sec
stream width-depth	0.91 - 0.21 m
stream order	1 st

Sediment Flows:

1974	
Sediment Concentration	
mean seasonal	
upstream	24.0 mg/1
downstream	309.0 mg/1
storms	
June 21-28, 1974	
upstream	42.0 mg/1
downstream	640.0 mg/1
July 9-13, 1974	
upstream	91.0 mg/1
downstream	1084.0 mg/1
Sediment Production	
seasonal	201.55 kg/ha/day
storm	
June 21-18, 1974	392.6 kg/ha/day
July 9-13, 1974	660.5 kg/ha/day
1975	
Sediment Concentration	
mean seasonal	
upstream	55.0 mg/1
downstream	516.0 mg/1
storms	
June 28-30, 1975	
upstream	89.0 mg/1
downstream	1539.0 mg/1
Sediment Production	
seasonal	346.9 kg/ha/day
storm	
June 28-30, 1975	633.6 kg/ha/day

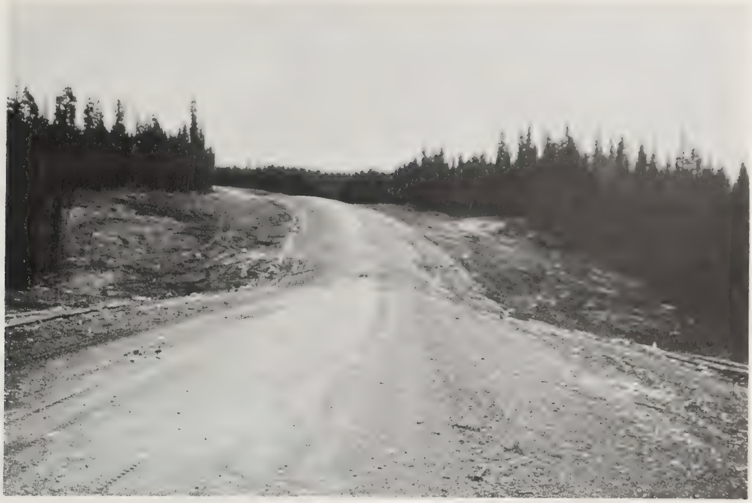


Figure 94. ER3 - East Half Following Grass Sowing June 1974.

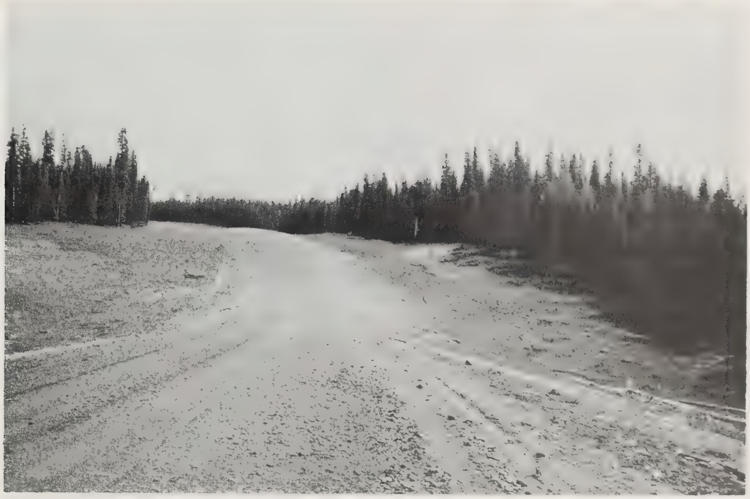


Figure 95. ER3 - East Half in August 1974.

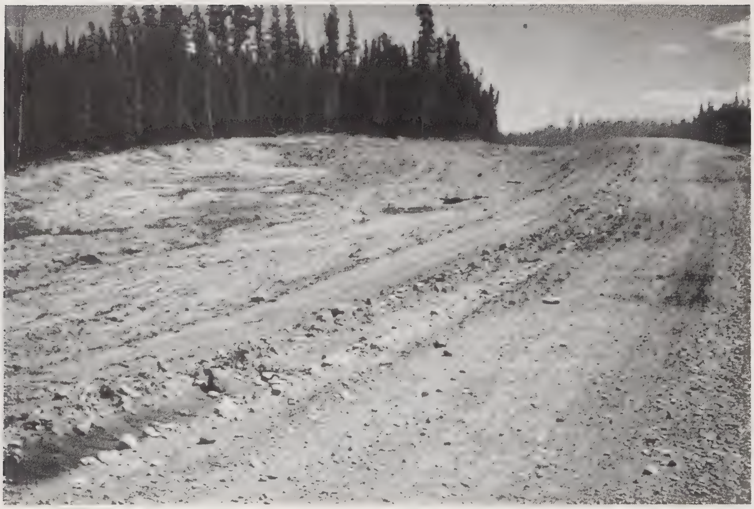


Figure 96. ER3 - NE Quadrant Following Grass Sowing - 1974.

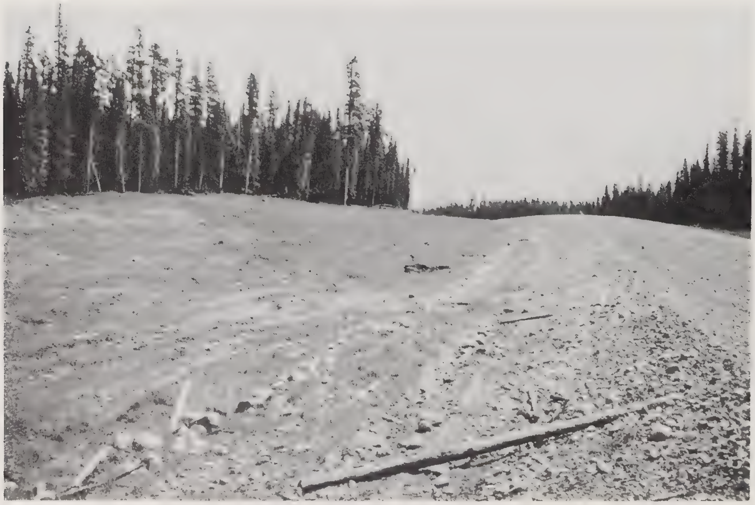


Figure 97. ER3 - NE Quadrant in August 1974.

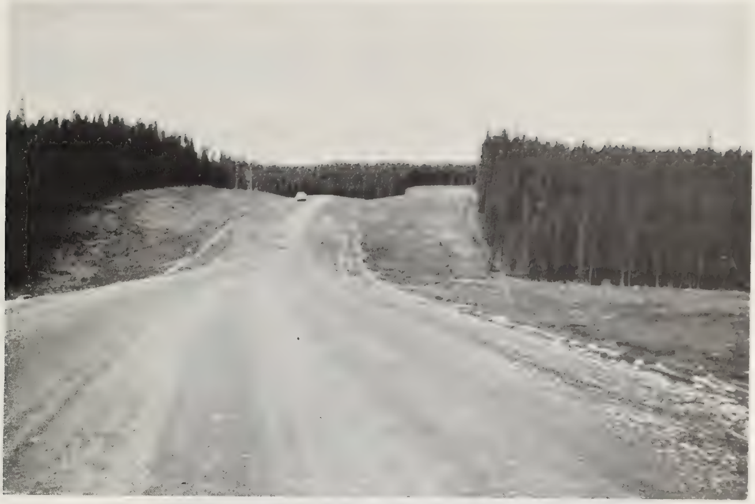


Figure 98. ER3 - West Half in Spring of 1975 Prior to New Grass Growth. Vegetation was Still Sparse.

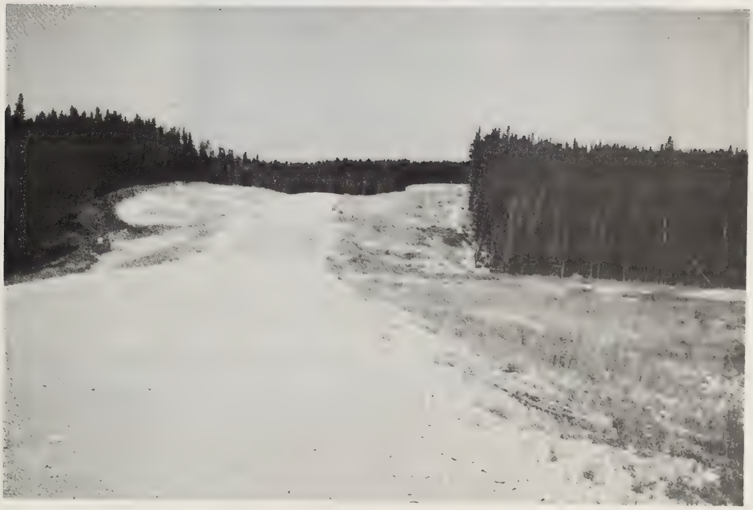


Figure 99. ER3 - West Half in August 1976. Vegetation Sparse - Spotty in Coverage.

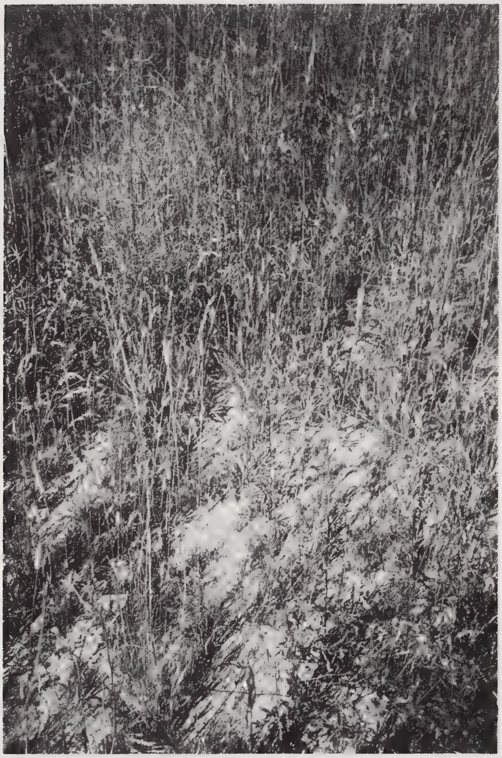


Figure 100. ER3 - Grass Cover on NE Quadrant August 1976. Compared to ER1, ER2, Vegetative Cover was Sparse.

Figure 101

Road Stream Crossing ER-3
Sediment Flows 1974: May-August

Taken at downstream sampling
station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

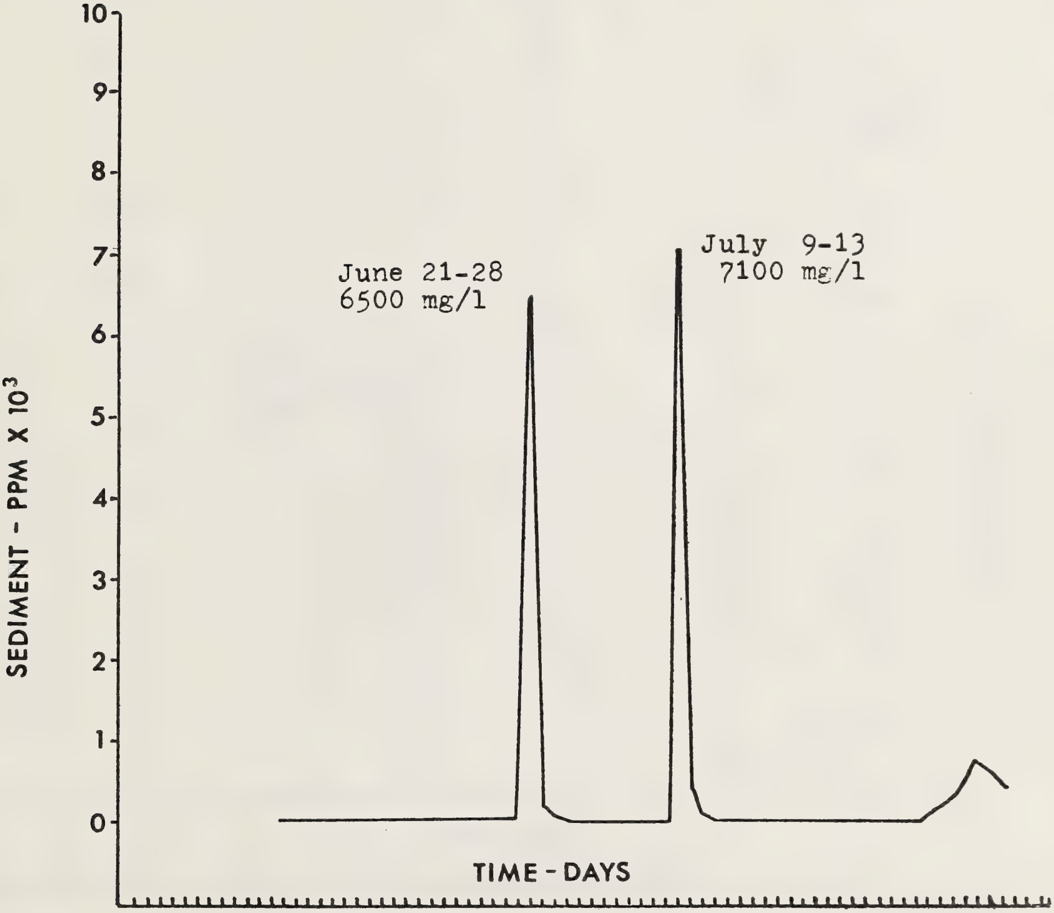


Figure 102
Road Stream Crossing ER-3
Sediment Flows 1975: May 15 - August 26

Taken at downstream sampling station

Ordinate: ppm or mg/l
Abscissa: 1 unit = 3 days

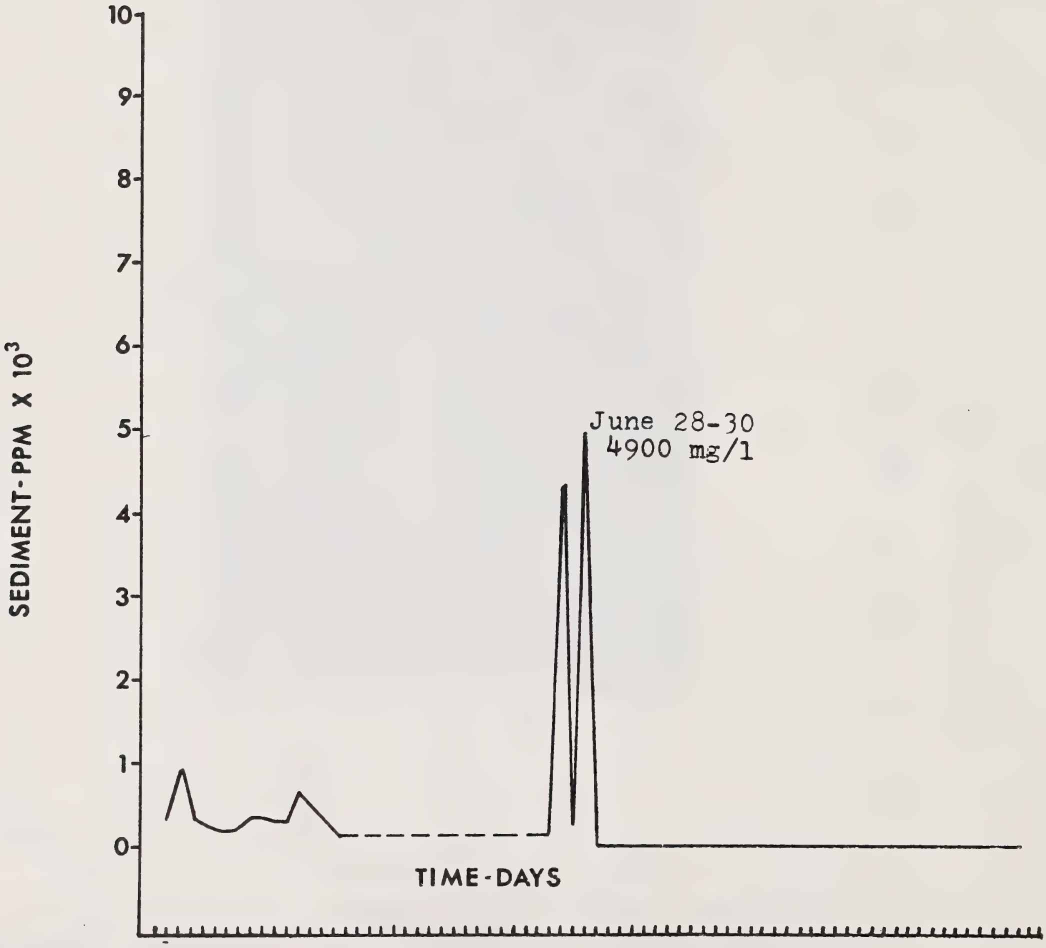


Figure 103
Road Stream Crossing ER-3
Sediment Production 1974: May 5 - August 23

Ordinate: lbs/day
Abscissa: 1 unit = 3 days

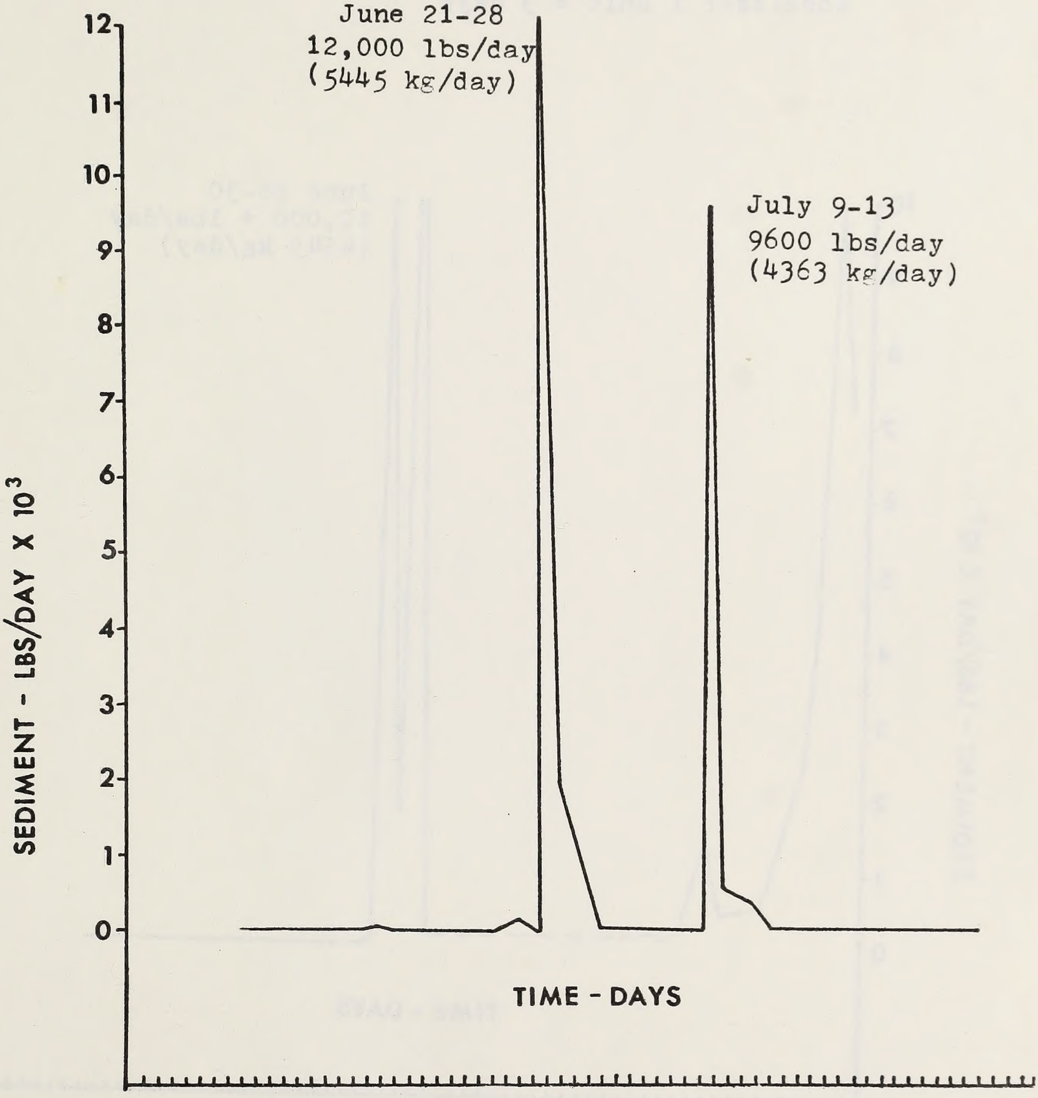
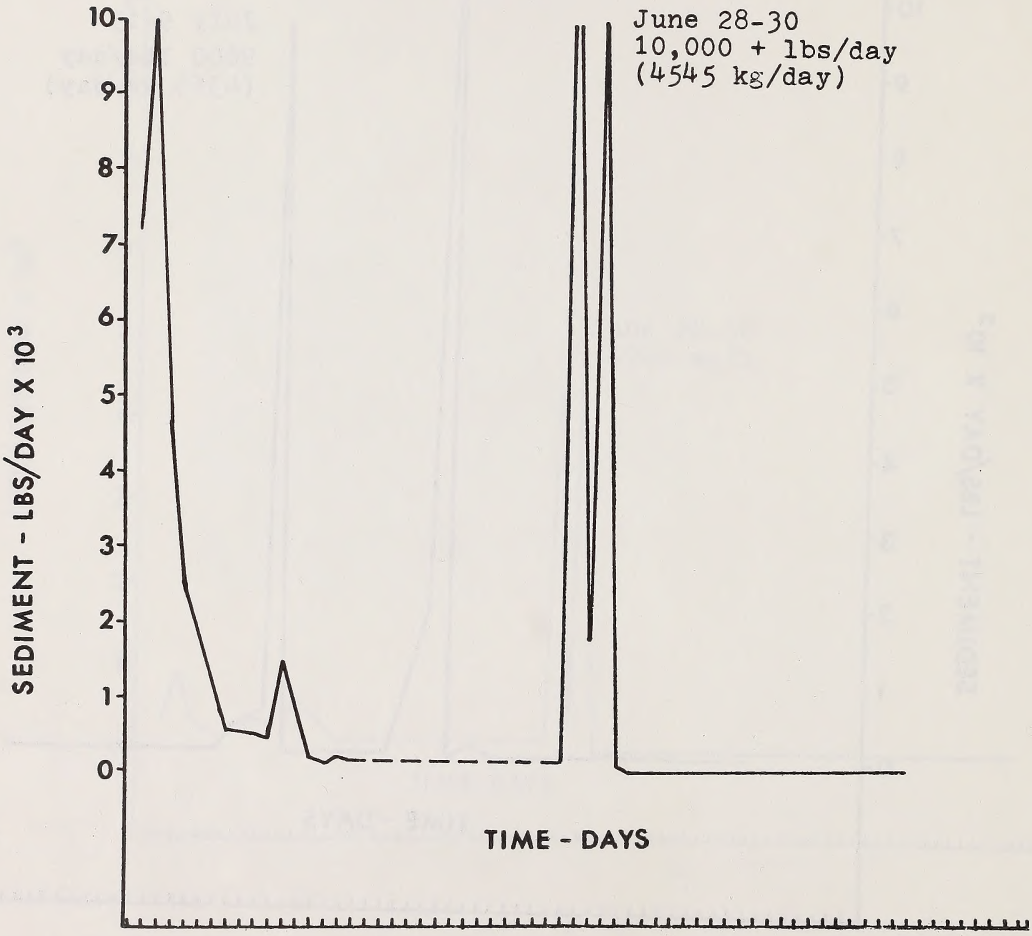


Figure 104
Road Stream Crossing ER-3
Sediment Production 1975: May 15- August 26

Ordinate: lbs/day
Abscissa: 1 unit = 3 days



N.L.C. - B.N.C.
3 3286 07315873 1